TECHNICAL MANUAL

ADDENDUM TO TECHNICAL MANUAL

888-1859-001

FM-25K TRANSMITTER

994 8258 001

NOTE

The information included in this addendum is to be added to the Technical Manual to reflect changes made since the Technical Manual was last revised. The inclusion of this material will update the Technical Manual to the equipment configuration at the time of shipment.

The addendum should remain with the Technical Manual to facilitate replaceable parts service at a later date.

HARRIS CORPORATION
Broadcast Division

T.M. No. 888-1859-006

Printed: August 11, 1983

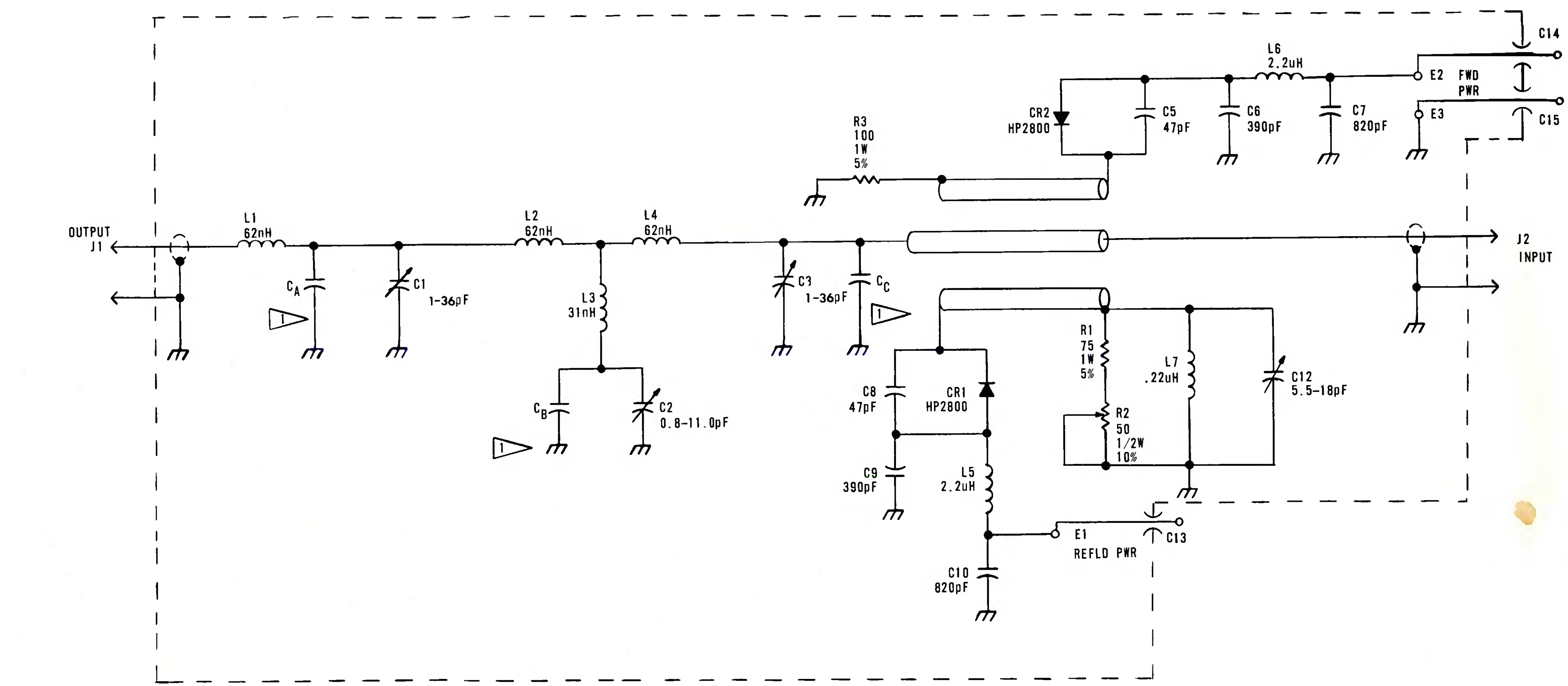
ECN 27628

Page 7-36, Table 7-20. Low Pass Filter/Directional Coupler Assembly - 992 5620 001.

<u>Change</u> C1 and C3, 517 0053 000, Capacitor, Variable, .8-23PF
<u>To</u> 517 0042 000, Capacitor, Variable, 1.0-23PF

Delete C4 and C11, 500 0803 000, Capacitor, 5PF, 500V

Page 8-21/8-22. Figure 8-10. Schematic IPA LOW PASS FILTER AND DIRECTIONAL COUPLER 839 5303 001. Replace Rev. A with Rev. B.



1 C_A, C_B, C_C, PRINTED CIRCUIT CAPACITORS

FIGURE 8-10. SCHEMATIC
IPA LOW-PASS FILTER AND
DIRECTIONAL COUPLER
839 5303 001

TECHNICAL MANUAL

ADDENDUM TO TECHNICAL MANUAL

888-1859-001

FM-25K TRANSMITTER

994 8258 001

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HARRIS CORPORATION
Broadcast Division

T.M. No. 888-1859-005

Printed: January 20, 1983

ECN 27403

Page 7-7, Table 7-5. IPA Module Assembly - 992 5352 001.

Change Q2,Q3, 380 0600 000, Transistor, CD2315 TO Q2,Q3, 380 0651 000, Transistor, SRF3344.

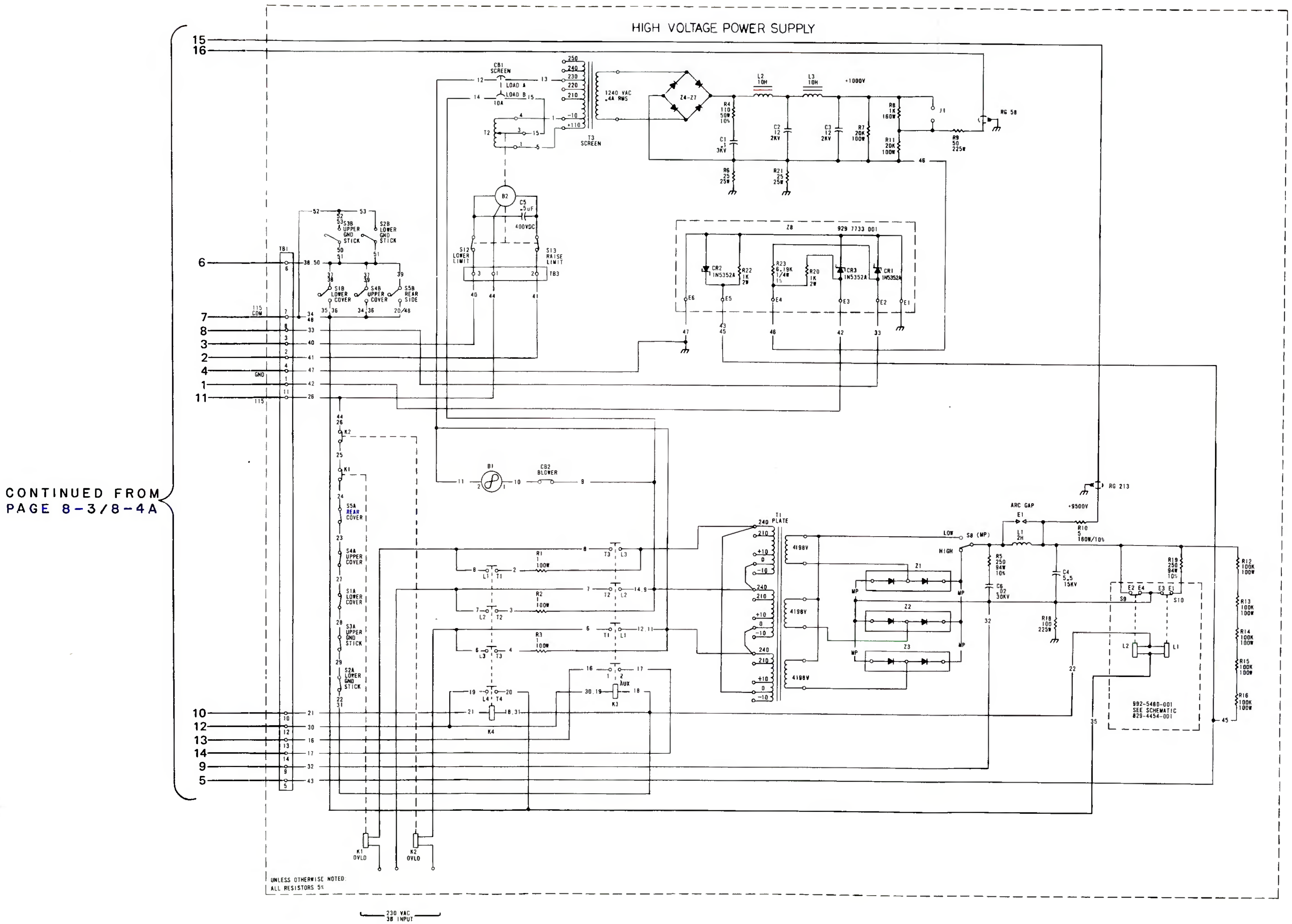

FIGURE 8-1. SCHEMATIC DIAGRAM
MAIN CABINET FM-25K TRANSMITTER
852 8806 001

TECHNICAL MANUAL

ADDENDUM TO TECHNICAL MANUAL

888-1859-001

NOTE

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HARRIS CORPORATION
Broadcast Division

T.M. No. 888-1859-004

Printed: October 14, 1982

ECN 27227

Replace Figure 8-1. MAIN CABINET SCHEMATIC DIAGRAM FM-25K TRANSMITTER 852 8806 001, page 8-3/8-4, with Rev. J.

TECHNICAL MANUAL

ADDENDUM TO TECHNICAL MANUAL

888-1859-001

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HARRIS CORPORATION
Broadcast Division

T.M. No. 888-1859-003

Printed: October 15, 1982

ECN 27138

Make the following changes to Table 7-22, page 7-42, AC Control PC Assembly, 992 5439 001:

Change resistors R5 and R8 from 4.7k ohms, 1/2W, 5%, 540 1114 000 to 5.1k ohms, 1/2W, 5%, 540 1105 000.

Update Figure 8-1, page 8-3/8-4, Main Cabinet Schematic Diagram, FM-25K Transmitter, 852 8806 001 from Rev. G to Rev. H by changing the value of R8 (on AC Control Board) from 4.7k to 5.1k.

TECHNICAL MANUAL

ADDENDUM TO TECHNICAL MANUAL

888-1859-001

The information included in this addendum is to be added to the Technical Manual to reflect changes made since the Technical Manual was last revised. The inclusion of this material will update the Technical Manual to the equipment configuration at the time of shipment.

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HARRIS CORPORATION

Broadcast Products Division

T.M. No. 888-1859-002

Printed: April 14, 1982

Add the following items to Technical Manual 888-1859-001, Table 7-27. High Voltage Power Supply - 992 5428 001: 817 1292 001, Standoff, Fiberglass, qty 12.

TECHNICAL MANUAL

FM-25K TRANSMITTER
(With IPA Metering)

HARRIS CORPORATION

Broadcast Products Division

T.M. No. 888-2000-571

WARNING

THE CURRENTS AND VOLTAGES IN THIS EQUIPMENT ARE DANGEROUS. PERSONNEL MUST AT ALL TIMES OBSERVE SAFETY REGULATIONS.

This manual is intended as a general guide for trained and qualified personnel who are aware of the dangers inherent in handling potentially hazardous electrical/electronic circuits. It is not intended to contain a complete statement of all safety precautions which should be observed by personnel in using this or other electronic equipment.

The installation, operation, maintenance and service of this equipment involves risks both to personnel and equipment, and must be performed only by qualified personnel exercising due care. HARRIS CORPORATION shall not be responsible for injury or damage resulting from improper procedures or from the use of improperly trained or inexperienced personnel performing such tasks.

During installation and operation of this equipment, local building codes and fire protection standards must be observed. The following National Fire Protection Association (NFPA) standards are recommended as references:

- Automatic Fire Detectors, No. 72E
- Installation, Maintenance, and Use of Portable Fire Extinguishers, No. 10
- Halogenated Fire Extinguishing Agent Systems, No. 12A

WARNING

ALWAYS DISCONNECT POWER BEFORE OPENING COVERS, DOORS, ENCLOSURES, GATES, PANELS OR SHIELDS. ALWAYS USE GROUNDING STICKS AND SHORT OUT HIGH VOLTAGE POINTS BEFORE SERVICING. NEVER MAKE INTERNAL ADJUSTMENTS, PERFORM MAINTENANCE OR SERVICE WHEN ALONE OR WHEN FATIGUED.

Do not remove, short-circuit or tamper with interlock switches on access covers, doors, enclosures, gates, panels or shields. Keep away from live circuits, know your equipment and don't take chances.

WARNING

IN CASE OF EMERGENCY ENSURE THAT POWER HAS BEEN DISCONNECTED.

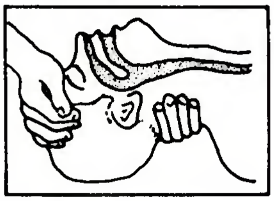
Treatment of Electrical Shock

1. If victim is not responsive follow the A-B-Cs of basic life support.

PLACE VICTIM FLAT ON HIS BACK ON A HARD SURFACE

(A) AIRWAY

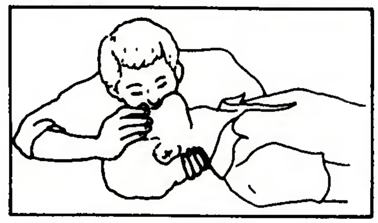
IF UNCONSCIOUS,
OPEN AIRWAY



LIFT UP NECK
PUSH FOREHEAD BACK
CLEAR OUT MOUTH IF NECESSARY
OBSERVE FOR BREATHING

(B) BREATHING

IF NOT BREATHING,
BEGIN ARTIFICIAL
BREATHING

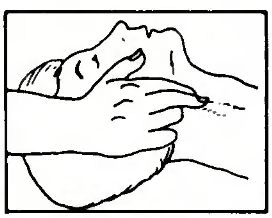


TILT HEAD
PINCH NOSTRILS
MAKE AIRTIGHT SEAL

4 QUICK FULL BREATHS

REMEMBER MOUTH TO MOUTH RESUSCITATION
MUST BE COMMENCED AS SOON AS POSSIBLE

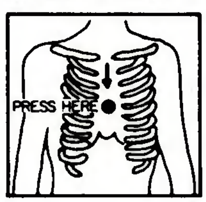
CHECK CAROTID PULSE



IF PULSE ABSENT,
BEGIN ARTIFICIAL
CIRCULATION

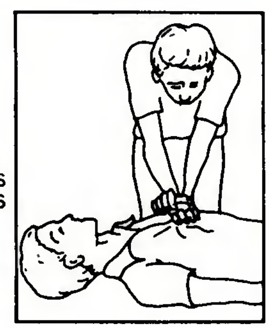
(C) CIRCULATION

DEPRESS STERNUM 1 1/2" TO 2"



APPROX. 80 SEC. { ONE RESCUER
15 COMPRESSIONS
2 QUICK BREATHS

APPROX. 60 SEC. { TWO RESCUERS
5 COMPRESSIONS
1 BREATH



NOTE: DO NOT INTERRUPT RHYTHM OF COMPRESSIONS
WHEN SECOND PERSON IS GIVING BREATH

Call for medical assistance as soon as possible.

2. If victim is responsive.

   a. keep them warm
   b. keep them as quiet as possible
   c. loosen their clothing
      (a reclining position is recommended)

FIRST-AID

Personnel engaged in the installation, operation, maintenance or servicing of this equipment are urged to become familiar with first-aid theory and practices. The following information is not intended to be complete first-aid procedures, it is brief and is only to be used as a reference. It is the duty of all personnel using the equipment to be prepared to give adequate Emergency First Aid and thereby prevent avoidable loss of life.

Treatment of Electrical Burns

1. Extensive burned and broken skin

   a. Cover area with clean sheet or cloth. (Cleanest available cloth article.)
   b. Do not break blisters, remove tissue, remove adhered particles of clothing, or apply any salve or ointment.
   c. Treat victim for shock as required.
   d. Arrange transportation to a hospital as quickly as possible.
   e. If arms or legs are affected keep them elevated.

NOTE

> If medical help will not be available within an hour and the victim is conscious and not vomiting, give him a weak solution of salt and soda: 1 level teaspoonful of salt and 1/2 level teaspoonful of baking soda to each quart of water (neither hot or cold). Allow victim to sip slowly about 4 ounces (a half of glass) over a period of 15 minutes. Discontinue fluid if vomiting occurs. (Do not give alcohol.)

2. Less severe burns - (1st & 2nd degree)

   a. Apply cool (not ice cold) compresses using the cleanest available cloth article.
   b. Do not break blisters, remove tissue, remove adhered particles of clothing, or apply salve or ointment.
   c. Apply clean dry dressing if necessary.
   d. Treat victim for shock as required.
   e. Arrange transportation to a hospital as quickly as possible.
   f. If arms or legs are affected keep them elevated.

REFERENCE: ILLINOIS HEART ASSOCIATION

AMERICAN RED CROSS STANDARD FIRST AID AND PERSONAL SAFETY MANUAL (SECOND EDITION)

SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION

1-2. This technical manual is intended to serve as an addendum to the Technical Manual 888 1859 001 FM-25K TRANSMITTER. The addendum consists of the following pages:

Page Number	Subject Matter
Cover Page	FM-25K TRANSMITTER (With IPA Multimeter)
ix/x	List of Tables/List of Illustrations
xi/xii	List of Illustrations/blank
7-3/7-4	Parts List
7-53/7-54	Parts List
8-1/8-2	Text/blank
8-47	Figure 8-15

1-3. INSTRUCTIONS

1-4. In the Technical Manual 888 1859 001 FM-25K TRANSMITTER, remove the following pages and insert the appropriate addendum page:

Page Number	Subject Matter
Cover Page	FM-25K TRANSMITTER
ix/x	List of Tables/List of Illustrations
xi/xii	List of Illustrations/blank
7-3/7-4	Parts List
8-1/8-2	Text/blank

1-5. Insert addendum pages 7-53/7-54 and 8-47.

WARNING: Disconnect primary power prior to servicing.

TECHNICAL MANUAL

FM-25K TRANSMITTER ADDENDUM

HARRIS CORPORATION
Broadcast Division

T.M. No. 888-2000-571

Printed: December 1982

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5-4.	Eight Port Combiner Component Locator	5-29
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5-6.	IPA Low-Pass Filter/Directional Coupler Board Component Location	5-31
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WARNING: Disconnect primary power prior to servicing.

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6-5.	IPA Driver Module RFA/RFB Indicators Illuminated - PA Module RFA/RFB Indicators Out	6-13
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8-1.	Main Cabinet Schematic Diagram, FM-25K Transmitter	8-3
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7-30	Extender Card for Controller	992 5646 001	7-52
7-31	IPA Multimeter Assembly	994 8491 001	7-53
7-32	IPA Multimeter PC Board	992 5718 001	7-54

Table 7-2. FM-25K Transmitter - 994 8258 108

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
1A1	994 7950 001	FM Exciter	1
B1	436 0212 000	Motor, 230/460V, 60 Hz, 3 PH, 2HP (For 216V to 250V Line)	--
B1 (Alternate)	436 0215 000	Motor, 200V, 60 Hz, 3 PH, 2 HP (For 190V to 215V Line)	--
B1	436 0216 000	Motor, 220/380V, 50 Hz, 3 PH, 2 HP (For 198V to 242V)	--
M1	636 0039 000	Meter, Elapsed Time, 60 Hz, 230V	1
M1 (Alternate)	636 0038 000	Meter, Elapsed Time, 50 Hz, 230V	--
V1	374 0151 000	Vacuum Tube, Eimac 8990	1
Unit 2	994 6172 001	Low-Pass Filter 88-92, 98-108 MHz	--
Unit 2 (Alternate)	994 6172 002	Low-Pass Filter 92-98 MHz	--
	994 9258 002	Basic FM-25K Transmitter	1

WARNING: Disconnect primary power prior to servicing.

Table 7-31. IPA Multimeter Assembly - 994 8491 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1	516 0080 000	Capacitor, .01 uF, 600V	1
M1	632 0942 000	Meter, 0-100 uA	1
	929 8179 001	Cable Ribbon	1
	650 0021 000	Knob	1
	992 5718 001	PC Board 1A14	1

Table 7-32. IPA Multimeter PC Board - 992 5718 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
J1	610 0746 000	Header, 20 Pin	1
R1 thru R5	548 1316 000	Resistor, 150 ohms, 1/4W, 1%	5
R6,R7	548 0815 000	Resistor, 1 megohm, 1/4W, 1%	2
S1	600 0592 000	Switch, Rotary, 12 Pos., 2 Pole	1

WARNING: Disconnect primary power prior to servicing.

SECTION VIII

DIAGRAMS

8-1. INTRODUCTION

8-2. This section provides schematic, interconnection, and wiring diagrams required for maintenance of the FM-25K TRANSMITTER. The following diagrams are contained in this section.

Figure	Title	Number	Page
8-1	Main Cabinet Schematic Diagram, FM-25K Transmitter	852 8806 001	8-3
8-2	Schematic Diagram, Digital, Analog, and Status Boards	852 8792 001	8-5
8-3	Schematic Diagram, Logic Section Motherboard	852 8808 001	8-7
8-4	Schematic Diagram, RFI Filter Assembly	852 8807 001	8-9
8-5	PA Efficiency Curve	1859-9	8-11
8-6	Schematic Diagram, IPA Section Motherboard	852 8735 001	8-13
8-7	Schematic Diagram, IPA Combiner/Splitter	839 4830 001	8-15
8-8	Schematic Diagram, IPA RF Amplifier Module	843 3059 001	8-17
8-9	Schematic Diagram, IPA 8 Port Combiner	839 4913 001	8-19
8-10	Schematic, IPA Low-Pass Filter and Directional Coupler	839 5303 001	8-21
8-11	Main Cabinet Transformer Wiring Diagram	1859-17	8-23
8-12	High Voltage Cabinet Transformer Wiring Diagram	1859-19	8-25
8-13	Wire List, Main Transmitter Cabinet (8 Sheets)	817 0591 001	8-27
8-14	Wire List, High Voltage Power Supply (2 Sheets)	817 0548 001	8-43
8-15	Schematic Diagram, IPA Multimeter Board	839 5634 001	8-47

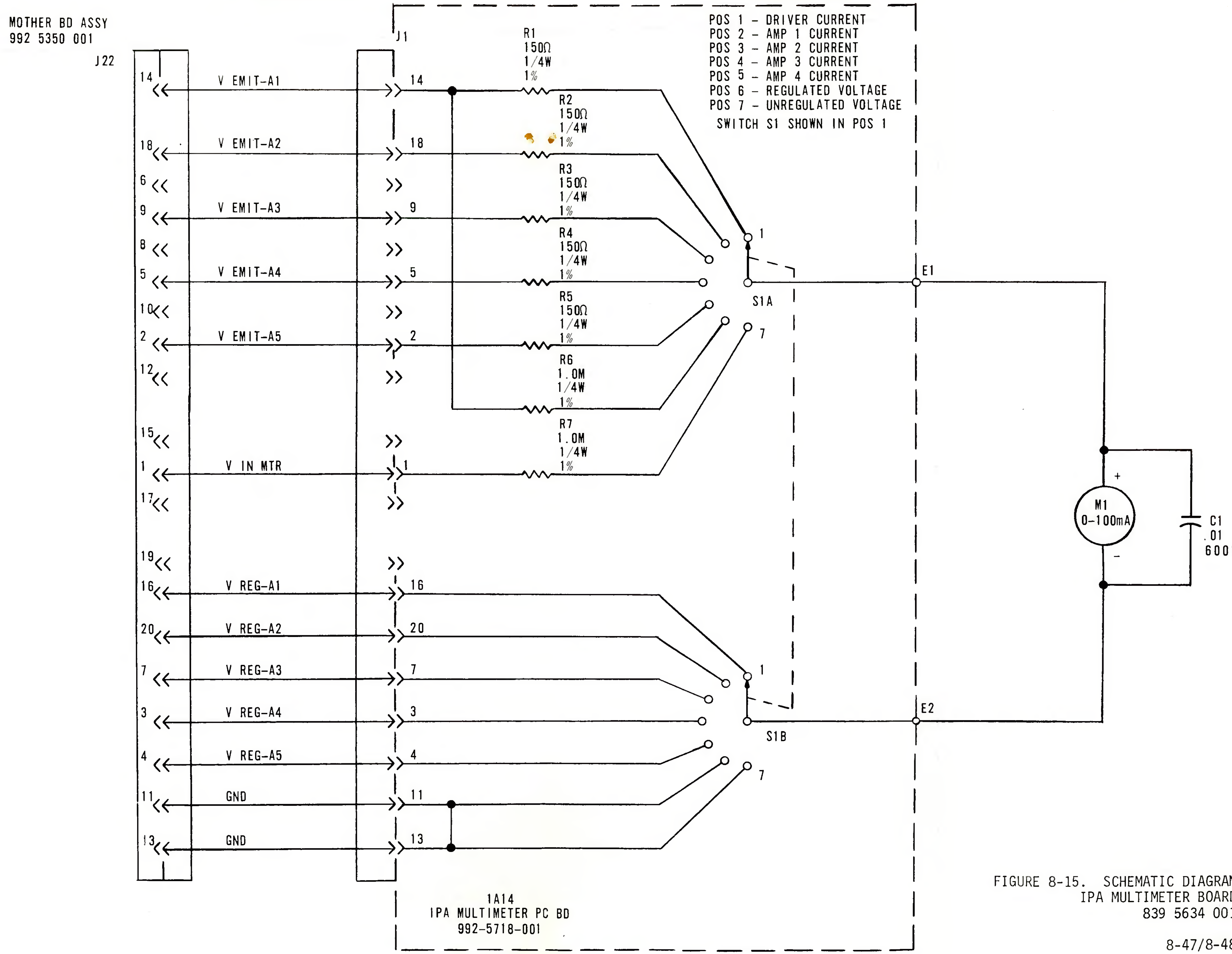


FIGURE 8-15. SCHEMATIC DIAGRAM
IPA MULTIMETER BOARD
839 5634 001

TECHNICAL MANUAL

FM-25K TRANSMITTER

994 8258 001

HARRIS CORPORATION

Broadcast Products Division

T.M. No. 888 1859 001

Printed: December 1979
Revision A: April 1980
Revision B: July 1981
Revision C: March 1982

MANUAL REVISION HISTORY

MCN OR REV.NO.	MCN OR REV. DATE	ECN NO.	DESCRIPTION OF CHANGE
			Revision A: April 1980
			Revision B: July 1981
B-1	11/09/81	26534	Page 7-32, Table for 992 5436 001 Change C1, C2 from 526 0093 000, Capacitor, 15 uF, 35V to 526 0238 000, Capacitor, 33 uF, 35V, 20%
			Figure 8-3, Change schematic 852 8808 001 to Revision A by changing C1 and C2 to 33 uF.
		26582	Page 7-19, Table for 992 5433 001 Change R2 from 540 0898 000, Resistor, 270 ohms, 1/4W, 5% to 540 1176 000, Resistor, 120 ohms, 1/4W, 5%
			Page 7-21, Table for 992 5433 001 Change R42 from 540 0912 000, Resistor, 1k ohm, 1/4W, 5% to 540 1130 000, Resistor, 620 ohms, 1/4W, 5%
			Figure 8-2, Change schematic 852 8792 001 from Rev. D to Rev. E by changing the value of resistors R2 and R42.
		26395	Section 8, Figure 8-1 Change schematic 852 8806 001 from Rev. E to Rev. F.
			Section 8, Figure 8-13 Change Wire List, Main Transmitter Cabinet from Rev. A to Rev. B.
		26627	Page 7-19, Table for 992 5433 001 Change R2 from 540 1176 000, Resistor, 120 ohms, 1/2W, 5% to 540 0890 000, Resistor, 120 ohms, 1/4W, 5%.

MANUAL REVISION HISTORY

MCN OR REV.NO.	MCN OR REV. DATE	ECN NO.	DESCRIPTION OF CHANGE
			Page 7-21, Table for 992 5433 001 Change R42 from 540 1130 000, Resistor, 620 ohms, 1/2W, 5% to 540 0907 000, Resistor, 620 ohms, 1/4W, 5%.
		25158	Table 7-13, page 7-18. Change capacitors C47 thru C53 from .33 uF, 35V, PN 526 0331 000 to .01 uF, 50V, PN 526 0375 000.
			Table 7-13, page 7-21. Change resistor, R45 from 1k, 1/4W, 5%, PN 540 0912 00 to 47k, 1/4W, 5%, PN 540 0952 000.
			Table 7-13, page 7-21. Change resistor, R52 from 3k, 1/4W, 5%, PN 540 0923 000 to 18k, 1/4W, 5%, PN 540 0942 000.
			Table 7-13, page 7-22. Change resistor, R90 from 10k, 1/4W, 5%, PN 540 0936 000 to 100 ohms, 1/4W, 5%, PN 540 0888 000.
			Schematic 852 8792 001, Figure 8-2, page 8-5/8-6 is updated from Rev. B to Rev. C. according to the above changes.
		25332	Table 7-22, page 7-42. Change resistor, R20 from 2.4k, 1/2W, 5%, PN 540 1193 000 to 220 ohms, 1/2W, 5%, PN 540 1118 000.
			Table 7-22, page 7-43. Change resistor, R23 from 4.7k, 1/2W, 5%, PN 540 1114 000 to 470 ohms, 1/2W, 5%, PN 540 1115 000.
			Schematic 852 8806 001, Figure 8-1, page 8-3/8-4 is updated from Rev. C to Rev. D according to the above changes.

MANUAL REVISION HISTORY

MCN OR REV.NO.	MCN OR REV. DATE	ECN NO.	DESCRIPTION OF CHANGE
			MCR* 784-81-047
B-2	12/07/81	26717	On page 7-41, Table for 992 5439 001, delete C24, 500 0912 000, Capacitor, 820 pF, 500 V and change qty to 2.
			On page 7-46, table for 992 5349 001, add C24, 500 0803 000, Capacitor, 5 pf, 500V, qty 1.
B-3	01/06/82	MCR*	Under the WARNING after paragraph 2-27 add the following CAUTION.
			UNLESS INSTRUCTED TO THE CONTRARY, OVERLOAD RELAYS K1 AND K2 ARE OPERATED WITHOUT SILICONE FLUID INSTALLED IN THE DASHPOT CUP. THIS INSURES THE OVERLOAD RELAYS WILL OPERATE AT THE 100% VALUE OF OVERLOAD CURRENT, MUCH LIKE A FAST BLOW FUSE. SEE MANUFACTURERS DATA SHEETS FOR DETAILED RELAY OPERATION.
		25784	Change figure 8-1, Main Cabinet Schematic Diagram, FM-25K Transmitter, 852 8806 001 to Rev. G.
B-4	01/18/82	ENG REQUEST	Add Addendum entitled "Harris Engineering Department Power Distribution Recommendation".
B-5	03/30/82	ERRATA	Make the following changes to the List of Illustrations on page xii: 6-9. Control Circuit Inoperative (Filament Off Sequence)...6-19; 6-10. Control Circuit Inoperative (Plate Off Sequence).. 6-25.

MANUAL REVISION HISTORY

MCN OR REV.NO.	MCN OR REV. DATE	ECN NO.	DESCRIPTION OF CHANGE
			In Table 6-3, on page 6-5 change the wording under CONTROL CIRCUIT INOPERATIVE to FILAMENT ON SEQUENCE Refer to figure 6-8.; FILAMENT OFF SEQUENCE Refer to figure 6-10 (2 sheets); PLATE OFF SEQUENCE Refer to figure 6-11. On figure 6-9, pages 6-19/6-20, change title to FIGURE 6-9. CONTROL CIRUIT INOPERATIVE (FILAMENT OFF SEQUENCE) On figure 6-10, pages 6-21/6-22 and 6-23/6-24, change title to FIGURE 6-10. CONTROL CIRCUIT INOPERATIVE (PLATE ON SEQUENCE) Add figure 6-11, page 6-25/6-26, entitled FIGURE 6-11. CONTROL CIRCUIT INOPERATIVE (PLATE OFF SEQUENCE) Revision C: March 1982

WARNING

THE CURRENTS AND VOLTAGES IN THIS EQUIPMENT ARE DANGEROUS. PERSONNEL MUST AT ALL TIMES OBSERVE SAFETY REGULATIONS.

This manual is intended as a general guide for trained and qualified personnel who are aware of the dangers inherent in handling potentially hazardous electrical/electronic circuits. It is not intended to contain a complete statement of all safety precautions which should be observed by personnel in using this or other electronic equipment.

The installation, operation, maintenance and service of this equipment involves risks both to personnel and equipment, and must be performed only by qualified personnel exercising due care. HARRIS CORPORATION shall not be responsible for injury or damage resulting from improper procedures or from the use of improperly trained or inexperienced personnel performing such tasks.

During installation and operation of this equipment, local building codes and fire protection standards must be observed. The following National Fire Protection Association (NFPA) standards are recommended as references:

- Automatic Fire Detectors, No. 72E
- Installation, Maintenance, and Use of Portable Fire Extinguishers, No. 10
- Halogenated Fire Extinguishing Agent Systems, No. 12A

WARNING

ALWAYS DISCONNECT POWER BEFORE OPENING COVERS, DOORS, ENCLOSURES, GATES, PANELS OR SHIELDS. ALWAYS USE GROUNDING STICKS AND SHORT OUT HIGH VOLTAGE POINTS BEFORE SERVICING. NEVER MAKE INTERNAL ADJUSTMENTS, PERFORM MAINTENANCE OR SERVICE WHEN ALONE OR WHEN FATIGUED.

Do not remove, short-circuit or tamper with interlock switches on access covers, doors, enclosures, gates, panels or shields. Keep away from live circuits, know your equipment and don't take chances.

WARNING

IN CASE OF EMERGENCY ENSURE THAT POWER HAS BEEN DISCONNECTED.

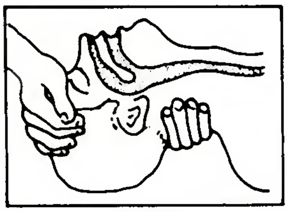
Treatment of Electrical Shock

1. If victim is not responsive follow the A-B-Cs of basic life support.

PLACE VICTIM FLAT ON HIS BACK ON A HARD SURFACE

(A) AIRWAY

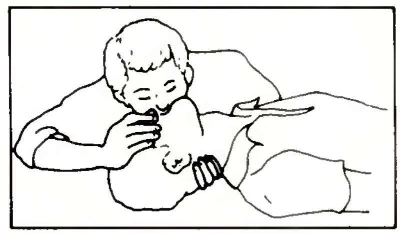
IF UNCONSCIOUS,
OPEN AIRWAY



LIFT UP NECK
PUSH FOREHEAD BACK
CLEAR OUT MOUTH IF NECESSARY
OBSERVE FOR BREATHING

(B) BREATHING

IF NOT BREATHING,
BEGIN ARTIFICIAL
BREATHING

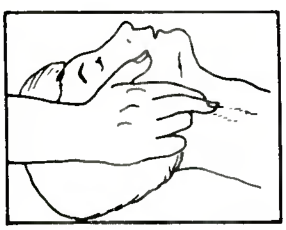


TILT HEAD
PINCH NOSTRILS
MAKE AIRTIGHT SEAL

4 QUICK FULL BREATHS

REMEMBER MOUTH TO MOUTH RESUSCITATION
MUST BE COMMENCED AS SOON AS POSSIBLE

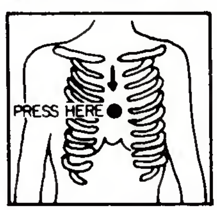
CHECK CAROTID PULSE



IF PULSE ABSENT,
BEGIN ARTIFICIAL
CIRCULATION

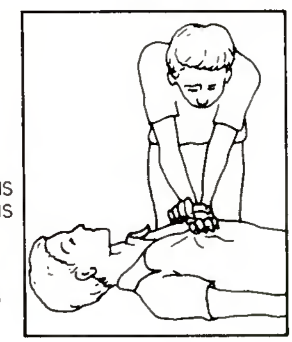
(C) CIRCULATION

DEPRESS STERNUM 1 1/2" TO 2"



APPROX. 80 SEC. { ONE RESCUER
15 COMPRESSIONS
2 QUICK BREATHS

APPROX. 60 SEC. { TWO RESCUERS
5 COMPRESSIONS
1 BREATH



NOTE: DO NOT INTERRUPT RHYTHM OF COMPRESSIONS
WHEN SECOND PERSON IS GIVING BREATH

Call for medical assistance as soon as possible.

2. If victim is responsive.

   a. keep them warm
   b. keep them as quiet as possible
   c. loosen their clothing
   (a reclining position is recommended)

FIRST-AID

Personnel engaged in the installation, operation, maintenance or servicing of this equipment are urged to become familiar with first-aid theory and practices. The following information is not intended to be complete first-aid procedures, it is brief and is only to be used as a reference. It is the duty of all personnel using the equipment to be prepared to give adequate Emergency First Aid and thereby prevent avoidable loss of life.

Treatment of Electrical Burns

1. Extensive burned and broken skin

   a. Cover area with clean sheet or cloth. (Cleanest available cloth article.)
   b. Do not break blisters, remove tissue, remove adhered particles of clothing, or apply any salve or ointment.
   c. Treat victim for shock as required.
   d. Arrange transportation to a hospital as quickly as possible.
   e. If arms or legs are affected keep them elevated.

NOTE

If medical help will not be available within an hour and the victim is conscious and not vomiting, give him a weak solution of salt and soda: 1 level teaspoonful of salt and 1/2 level teaspoonful of baking soda to each quart of water (neither hot or cold). Allow victim to sip slowly about 4 ounces (a half of glass) over a period of 15 minutes. Discontinue fluid if vomiting occurs. (Do not give alcohol.)

2. Less severe burns - (1st & 2nd degree)

   a. Apply cool (not ice cold) compresses using the cleanest available cloth article.
   b. Do not break blisters, remove tissue, remove adhered particles of clothing, or apply salve or ointment.
   c. Apply clean dry dressing if necessary.
   d. Treat victim for shock as required.
   e. Arrange transportation to a hospital as quickly as possible.
   f. If arms or legs are affected keep them elevated.

REFERENCE: ILLINOIS HEART ASSOCIATION

AMERICAN RED CROSS STANDARD FIRST AID AND PERSONAL SAFETY MANUAL (SECOND EDITION)

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SECTION I

GENERAL DESCRIPTION

1-1. INTRODUCTION

1-2. This technical manual contains information necessary to install, operate, maintain and service the FM-25K FM Broadcast Transmitter. Sections in this technical manual provide the following information.

a. SECTION I, GENERAL DESCRIPTION, provides a description of equipment features, identifies the major components and lists operating parameters and specifications.

b. SECTION II, INSTALLATION, provides unpacking, inspection and installation information, pre-operational checks and power on checks to ensure correct operation.

c. SECTION III, OPERATION, identifies controls and indicators and provides equipment and operation procedures.

d. SECTION IV, PRINCIPLES OF OPERATION, provides a functional description and detailed diagrams with theory of operation.

e. SECTION V, MAINTENANCE, provides preventive and corrective maintenance information with instructions for equipment servicing.

f. SECTION VI, TROUBLESHOOTING, provides charts to aid in locating equipment malfunctions.

g. SECTION VII, PARTS LIST, provides information for ordering replacement components and assemblies.

h. SECTION VIII, DIAGRAMS, provides block, logic, schematic diagrams and other drawings required for equipment maintenance.

1-3. RELATED PUBLICATIONS

1-4. The following publications provide information related to associated equipment.

PUBLICATION NUMBER	EQUIPMENT IDENTIFICATION
888 1742 001 thru 009	MS-15 FM Exciter

1-5. EQUIPMENT PURPOSE

1-6. The Harris FM-25K is a 25,000 watt commercial FM transmitter designed for continuous broadcast operation (see figure 1-1). The transmitter uses the Harris MS-15 FM Exciter, a solid-state driver, and a single tube as a PA stage to provide reliable and efficient operation in the 87.5 to 108 MHz commercial FM broadcast band. Exciter plug-in modules provide monaural or

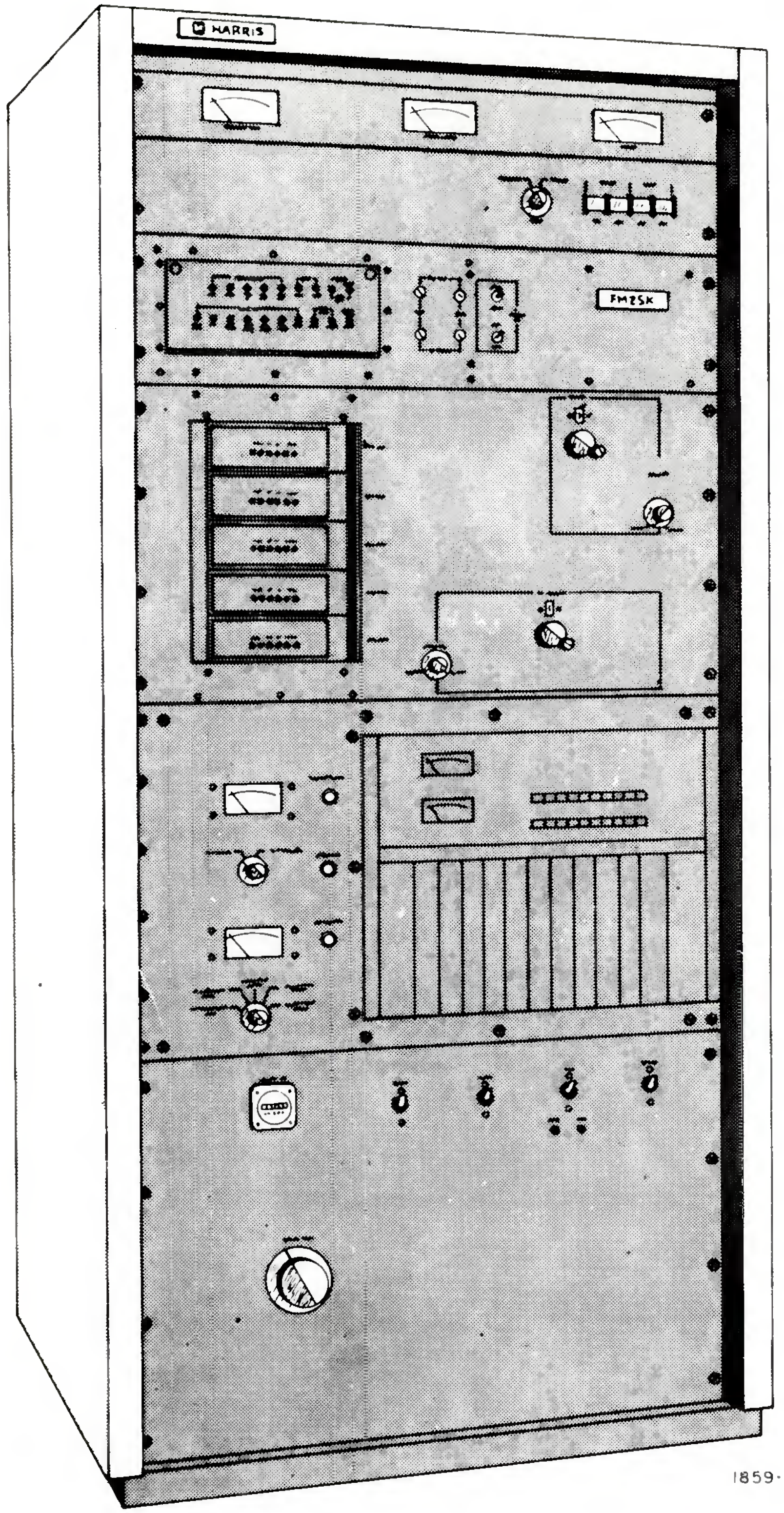


Figure 1-1. FM-25K Transmitter

stereophonic operation with up to two SCA channels. The modular construction of the exciter allows plug-in operation of a future quadraphonic transmission system.

1-7. PHYSICAL DESCRIPTION

1-8. The unit is contained in a single cabinet, with the exception of the high voltage and screen power supply enclosure. The cabinet size and the internal placement of the second harmonic filter ensures the transmitter will fit in the place of many older 20 to 25 kW FM Transmitters.

1-9. The high voltage and screen power supplies are located externally in a single enclosure cabinet which provides increased maintenance accessibility and working room. The power supply may be located next to the transmitter or placed in a remote location.

1-10. The main cabinet rear door is hinged and may be removed for maintenance access.

1-11. Required metering is provided by five meters located on the equipment front panel. An arrangement of light emitting diode status indicators provides visual indications of transmitter operation. All controls required for normal operation are accessible in full view of all indicators.

1-12. FUNCTIONAL DESCRIPTION

1-13. POWER SUPPLIES

1-14. A three-wire source of three-phase 208 to 240 Vac at 100 amperes-per-phase or a four-wire source of 360 to 415 Vac at 65 amperes-per-phase is required to operate the FM-25K Transmitter High Voltage Power Supply. Additionally, a separate three-phase input at 30 amperes-per-phase source is required to operate the FM-25K Transmitter Cabinet power supplies. All power supplies are overload-protected and full-wave rectified using solid-state diodes.

1-15. The following power supplies are contained within the transmitter cabinet (see figure 1-2):

a. IPA DRIVER AND IPA AMP: +32 Vdc at 40 amperes.

b. CONTROL LOGIC: ±18 Vdc at 1.0 amperes and ±12 Vdc at 1.0 amperes.

c. CONTROL GRID BIAS: -500 Vdc at 0.1 amperes.

d. PA FILAMENT: 10.5 Vac at 150 amperes.

e. POWER ADJUST MOTOR: 24 Vac at 2.0 amperes.

f. RELAY AND SOLENOID SWITCHING: 115 Vac at 2.0 amperes.

1-16. The following power supplies are contained within the high voltage power supply cabinet (see figure 1-2).

a. PLATE: +9500 Vdc or +4250 Vdc at 4.0 amperes.

b. SCREEN GRID: +1050 Vdc at 0.4 amperes.

1-17. Current to the IPA DRIVER and IPA AMP modules is supplied through a current foldback type darlington stage voltage regulator mounted on each module. Each regulator is capable of operating with a continuous short on its output safely, without causing damage. A single FM-25K front panel control adjusts the output of all the module regulators simultaneously.

1-18. FM EXCITER

1-19. The FM exciter produces a frequency modulated output continuously variable from 3 to 15 watts into a 50 ohm load for any channel assignment within the 87.5 to 108 MHz commercial FM broadcast band. Servicing is simplified as the exciter is modular in concept and discrete functions are complete within individual plug-in modules. The metering panel contains a true peak reading audio meter and a multimeter which monitors important RF, audio and control voltages. Light emitting diode status indicators monitor critical functions on each plug-in module. Operational modes include up to two SCA channels, monophonic, stereophonic and provisions for future quadraphonic transmission. Refer to the exciter publication for a detailed description.

1-20. IPA STAGE

1-21. AMPLIFIER MODULES. The IPA amplifier circuit is modular on five printed circuit boards (one IPA DRIVER and four IPA AMP modules). Each module contains two solid-state amplifiers in a broadband amplifier circuit. The broadband input circuit presents a low VSWR to the FM exciter and a broadbanded combiner output circuit allows the failure of an IPA AMP module without causing an off-the-air condition.

1-22. As the IPA DRIVER module and the four IPA AMP modules are identical, if the IPA DRIVER module should fail, an IPA AMP module can be interchanged with the IPA DRIVER module for continued operation at typically 80 percent reduction of RF output power. Each module is rated at 100 watts, with the IPA section RF output rated at the nominal level of 350 watts. Light emitting diode status indicators on each module indicate the condition of the amplifiers and front panel test points allow measurement of the relative RF power output level of each amplifier with a dc voltmeter.

1-23. Each module is overload protected by fuses mounted on the motherboard and powered by individual monolithic voltage regulators providing foldback current protection. The reference which establishes the output of the regulators is obtained from the IPA DRIVER module. This reference voltage is adjusted by the front panel IPA OUTPUT PWR ADJ control and applied to all module regulators to allow a simultaneous adjustment of the RF output of all modules.

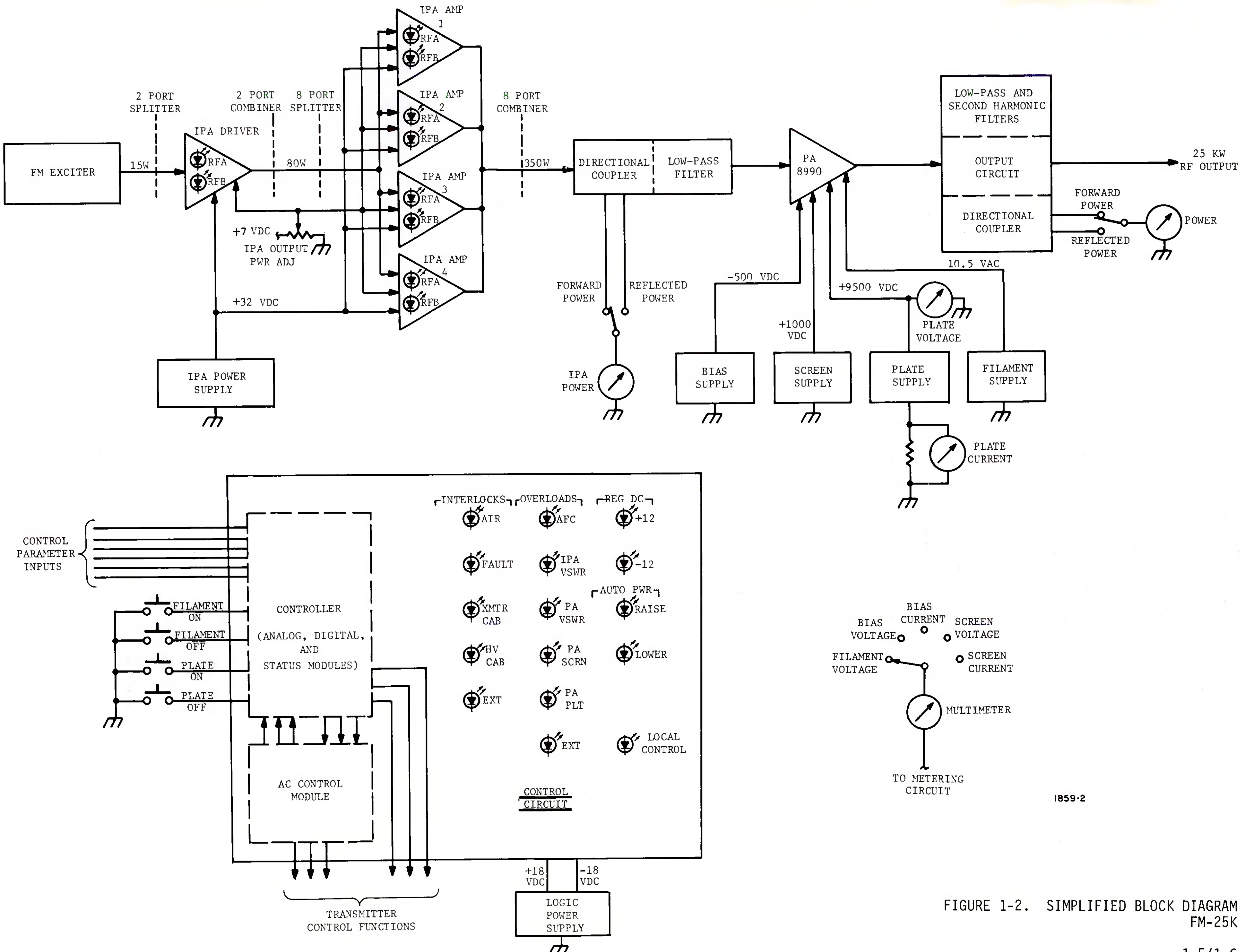


FIGURE 1-2. SIMPLIFIED BLOCK DIAGRAM
FM-25K

1-24. COMBINER/SPLITTER CIRCUITS. The splitter and combiner circuits are high efficiency passive units which perform the functions of splitting or combining the output(s) of an amplifier as required to provide isolated multiple outputs or a combined output of the proper impedance necessary to drive the following circuitry.

1-25. The two port splitter divides the 15 watt RF input from the FM exciter into two equal in-phase power levels to drive the IPA DRIVER module. The two port combiner combines the two 40 watt in-phase RF output signals into one 80 watt level to drive the four IPA AMP modules.

1-26. The eight port splitter divides the 80 watt input from the two port combiner into eight in-phase RF outputs of ten watts each as required to drive the IPA modules. The eight port combiner combines the eight high power outputs of the IPA stage into a single signal of approximately eight times the output level of a single amplifier. The high power RF output of the eight port combiner is applied to the transmitter output circuitry.

1-27. OUTPUT CIRCUIT. The IPA output circuit is complete on one printed circuit board, comprising a low-pass filter and a directional coupler. The directional coupler is implemented with microstrip techniques and provides dc voltages representative of forward and reflected output power. The reflected power signal is used by the control circuit to initiate amplifier shutdown in the event of excessive IPA/PA VSWR. The placement of the low-pass filter ensures the directional coupler will sense IPA stage VSWR only.

1-28. PA STAGE

1-29. A single-ended 8990 tetrode is conservatively operated in the FM-25K as a class C RF output amplifier to produce a 25 kW RF output from the IPA input. Forced air cooling ensures cool operation and long tube life. The input impedance of the PA stage is 50 ohms. In the event of a total PA stage failure, the output of the IPA output circuit could be routed to the 50 ohm transmitter antenna load as an emergency back-up.

1-30. The quarter wavelength cavity used in the PA stage ensures a wide bandwidth is maintained through the PA stage. The tuning arrangement requires no sliding contacts within the cavity walls which could be damaged if moved across high-current points. The inductive plate network provides dc isolation between the plate circuit and the output circuit. This is a safety feature and additionally provides some immunity to lightning damage.

1-31. OUTPUT CIRCUIT. The RF output to the antenna is coupled through a second harmonic stub filter, directional coupler, and a low-pass filter arrangement. The second harmonic filter operates at dc ground potential for safety and further immunity from lightning damage. Special provisions allow connection of monitors directly to the transmission line at the RF transmitter output.

1-32. CONTROL CIRCUITS

1-33. The majority of the FM-25K control circuitry is located on two plug-in printed circuit boards. One circuit board is concerned with the logic and timing process and the second circuit board is concerned with analog interface. The control functions are divided into INTERLOCKS and OVERLOADS with corresponding front panel indicators for each function.

1-34. INTERLOCK CIRCUITS. Five parameters are monitored by the interlock circuitry. They are AIR, FAULT, XMTR CAB, HV CAB, and EXT. Should any interlock circuit open, high voltage will be removed from the transmitter and operation must be manually restored. An external interlock provision allows interface of an external interlock (such as a coaxial transfer switch) into the transmitter control circuitry.

1-35. OVERLOAD CIRCUITS. Six parameters are monitored by the overload circuitry. The AFC overload circuit interfaces with the FM exciter AFC loop. Should the loop unlock, the transmitter will shut down to prevent off-frequency transmission. The IPA VSWR and PA VSWR circuits monitor the reflected power levels present at the IPA DRIVER and the PA stage outputs. Should a high reflection develop at either point, the transmitter control logic will remove both high and low voltages. The PA SCRN and PA PLT indicators sense over-current conditions in the PA screen and the PA plate circuits. The EXT overload circuit allows interface of an external station overload into the transmitter circuitry.

1-36. Operation of an overload circuit will cause the transmitter to momentarily interrupt operation then automatically recycle and restore power to attempt to clear the fault. Jumper-plug programming of the control logic circuit board allows the transmitter to recycle either once or three times after an overload within 30 seconds before complete shut-down occurs. When shut-down does occur, both the respective OVERLOAD indicator and the FAULT INTERLOCK indicator will illuminate.

1-37. AUTOMATIC RF POWER CONTROL. The FM-25K allows automatic control of RF power output as a standard feature. After the automatic circuit is activated, the station can program the power control circuit to automatically maintain an established RF power output level within approximately 2% or 4% of a selected value.

1-38. AC POWER CONTROL. If a total power failure occurs during operation, the control circuit will automatically restore the transmitter to operation. If a single phase is lost during transmitter operation, the control circuit will shut the transmitter down completely. Operation must be manually restored by a normal turn-on sequence.

1-39. REMOTE CONTROL. Remote control and remote monitoring of various transmitter parameters is allowed by connections to terminal board TB1 (remote control command inputs), terminal board TB2 (remote control metering outputs), jack J2 (extended control panel connections), and jack J3 (status and overload indicator outputs). All remote control functions require a momentary contact between a terminal or pin of the interface connectors and the control circuit positive bus voltage. This arrangement removes the chance of the unintentional operation of a particular function by an accidental connection to ground.

1-40. INDICATORS

1-41. Two meters and an arrangement of light-emitting diodes provide status indications of exciter operation. Five meters, sixteen light-emitting diodes, and two switch/indicators provide status indications of overall transmitter operation. Two light-emitting diodes on each IPA module front panel give indications of the RF output of each amplifier.

1-42. Meters monitor plate voltage, plate current, transmitter forward and reflected power output, IPA forward and reflected power, and filament hours of operation. A five-position multimeter switch selects the specific parameters to be displayed by the multimeter. The multimeter will display PA filament voltage, PA control grid bias voltage and current, and PA screen grid voltage and current.

1-43. SAFETY

1-44. The FM-25K design provides safety features which ensure that no voltage potentials are accessible to operational personnel from the front panel. Additionally, no high voltage points are readily accessible to maintenance personnel unless a cabinet door or panel is opened. If a door or a power supply panel is opened when power is energized, interlocks will remove high voltage from both cabinets and operation will have to be manually restored.

1-45. EQUIPMENT CHARACTERISTICS

1-46. ELECTRICAL CHARACTERISTICS

1-47. Table 1-1 lists electrical operating characteristics and parameters of the FM-25K FM broadcast transmitter.

1-48. MECHANICAL CHARACTERISTICS

1-49. Table 1-2 lists physical and environmental characteristics of the FM-25K FM broadcast transmitter.

NOTE

Specifications subject to change without notice.

Table 1-1. Electrical Characteristics

FUNCTION	CHARACTERISTIC
PRIMARY POWER REQUIREMENTS:	
HIGH VOLTAGE POWER SUPPLY	208/240 Vac, three-phase, 50/60 Hz, three-wire at 100 amperes per phase or 360/415 Vac, three-phase, 50/60 Hz, four-wire at 65 amperes per phase.
TRANSMITTER CABINET	208/240 Vac, three-phase, 50/60 Hz, three-wire at 30 amperes per phase or 360/415 Vac, three-phase, 50/60 Hz, four-wire at 20 amperes per phase.
POWER CONSUMPTION (Typical for 25,000 watt output)	40 kW, maximum
POWER FACTOR	0.95, lagging
ALLOWABLE POWER LINE VARIATION (Slow)	±5%
RF POWER OUTPUT	Continuously variable 0 to 25 kW.
RF OUTPUT IMPEDANCE	50 ohms
RF FREQUENCY RANGE	87.5 to 108 MHz
MAXIMUM VSWR	1.7 to 1
RF OUTPUT TERMINATION	3.125 inch (7.94 cm) EIA flange
RF HARMONIC SUPPRESSION	Meets FCC requirements
REMOTE CONTROL:	
CONTROL FUNCTIONS	Momentary 20 mA contact to common 12V positive dc bus.
STATUS INDICATOR OUTPUTS	
CONTROL INDICATORS	Open collector outputs (+20 volts maximum).
OVERLOAD INDICATORS	Ground potential through 1000 ohms.

Table 1-1. Electrical Characteristics (Continued)

FUNCTION	CHARACTERISTIC
METERING OUTPUTS	Approximately 5 volts through buffer amplifiers.

Table 1-2. Mechanical/Environmental Characteristics

FUNCTION	CHARACTERISTIC
RACK DIMENSIONS:	
Transmitter:	34.6 inches (87.8 cm) wide 71.7 inches (182.1 cm) high 31.0 inches (78.7 cm) deep
High Voltage Power Supply:	48.0 inches (121.9 cm) wide 60.2 inches (152.9 cm) high 24.2 inches (61.5 cm) deep
WEIGHT:	
PACKED	
Domestic	2,700 pounds (1225 kg)
Export	3,000 pounds (1361 kg)
CUBEAGE	150 ft^3 (4.25 m^3)
OPERATING TEMPERATURE RANGE	-4° to 122°F (-20°C to +50°C). Maximum temperature at sea level, decreasing 3.6°F (2°C) per 1000 feet (305 meters) to 86°F (30°C) maximum at 10,000 feet above sea level.
MAXIMUM HUMIDITY	95%, Non-condensing
MAXIMUM ALTITUDE	10,000 feet (3048 meters) above sea level.
COOLING AIR REQUIREMENTS:	
Amplifier Exciter High Voltage Power Supply	1170 ft^3/minute (33.11m^3/minute) 122 ft^3/minute (3.45 m^3/minute) 550 ft^3/minute (15.57 m^3/minute)
AIR INLET SIZE	
Main Cabinet	16.4 inches x 23.6 inches (41.66 cm x 59.95 cm) rear door.

Table 1-2. Mechanical/Environmental Charactersitics (Continued)

FUNCTION	CHARACTERISTIC
High Voltage Power Supply	15.1 inches x 15.25 inches (38.35 cm x 38.74 cm)
AIR OUTLET SIZE	
Main Cabinet	16.5 inches x 28.1 inches (41.91 cm x 71.37 cm) top of cabinet
High Voltage Power Supply	Louvers in front and sides of cabinet.

SECTION II

INSTALLATION

2-1. INTRODUCTION

2-2. This section contains information for installing the FM-25K transmitter and performing pre-operational checks.

2-3. UNPACKING

2-4. Carefully unpack the FM-25K transmitter and perform a visual inspection to determine that no apparent damage was incurred during shipment. Retain the shipping materials until it has been determined that the unit is not damaged. The contents of the shipment should be as indicated on the packing list. If the contents are incomplete or if the unit is damaged electrically or mechanically, notify the carrier and Harris Corporation, Broadcast Products Division.

2-6. Each transmitter is thoroughly checked out and operated before shipment and the test results logged on the factory final test data sheets. These data sheets provide the user with specific detailed measurements and instructions relative only to the specific equipment to which the sheets are attached. The sheets will be found attached to the upper front panel of the transmitter. It is strongly suggested that these sheets are filed in the front of this manual for future use. These sheets will be referenced throughout the installation procedure for tuning instructions and meter indications.

2-6. INSTALLATION

2-7. Prior to installation, the manual should be carefully studied to obtain a thorough understanding of the principles of operation, circuitry and nomenclature. This will facilitate proper installation and initial checkout. Installation is accomplished in four steps: (1) transmitter placement, (2) component installation, (3) transmitter wiring, and (4) initial checkout.

2-8. COOLING AIR REQUIREMENTS

2-9. If a means of exhausting hot air from the transmitter enclosure or room is used, the duct system must not introduce any back pressure on the transmitter air exhaust. Allowances must be made for a minimum air flow of 1291 ft^3/minute (36.56 m^3/minute) to ensure that only a limited amount of direct heat is dissipated into the transmitter interior. The high voltage power supply requires an additional 550 ft^3/minute (15.57 m^3/-minute). The duct work must have a cross sectional area equal to the opening at the top of the transmitter. Sharp right angle bends in the duct system are not permissible. If it is necessary to turn a right angle, a radius type bend must be used. The exhaust fan in the duct system must overcome any duct losses and overcome any wind pressures if vented to the outside.

2-10. The ambient air temperature measured at the blower air intake must not rise above 122^{o}F (50^{o}C) under any circumstance.

2-11. TRANSMITTER PLACEMENT

2-12. Set the transmitter and high voltage power supply in place on a smooth and level location near power and signal cables (see figure 2-1). The high voltage power supply must be placed within reach of the 40 foot (12.2 meter) interconnecting cables. Ensure adequate cable length is allowed for any vertical rises. The floor must be capable of supporting the 775 pounds (352.3 kg) weight of the transmitter and the 1300 pound (590.9 kg) weight of the high voltage power supply.

2-13. The interconnecting cables may be trimmed to length if desired using the additional hardware supplied with the cables.

2-14. COMPONENT INSTALLATION

2-15. Components may be removed from the transmitter after final test for transport. The removal of components varies due to the method and requirements of shipment. Capacitors, connectors, cables, etc., are shipped in separate cartons. All removed items will be tagged to permit reinstallation in the transmitter. The transmitter side panels and rear door should be removed and left off until the installation is complete.

2-16. Items such as interconnecting wires and cables, shock mounted devices and miscellaneous small parts may be taped or tied in for shipment. Remove all tape, string and packing material that has been used for this purpose.

2-17. Symbol numbers and descriptions are provided on each removed component corresponding to the schematic diagram, parts list and packing list. Symbol numbers are also stenciled near the cabinet location of each removed item. Terminals and wires carry tags with information telling how to reconnect each item. Mounting hardware will be found either in small bags attached to each removed component or inserted in the tapped holes where each component mounts.

2-18. Arrange the removed components in separate groups according to where each was removed. Reinstall all components in their proper locations. Parts in the interior should be installed first. Specific instructions follow for the items listed below.

2-19. IPA MODULE INSTALLATION. Insert the four IPA Amplifier and the IPA Driver Modules. Ensure the module is in the card guides and the PC edge connector is engaged before using the locking/removal lever to lock the module in place.

2-20. MS-15 EXCITER INSTALLATION. It is highly recommended that two people be used for Exciter Installation. With one person in the rear of the transmitter to support the weight of the exciter, insert the exciter into the mounting and secure with the provided hardware. Connect the marked wires to terminal board TB-1 and the ac power plug to J2 on the rear of the exciter.

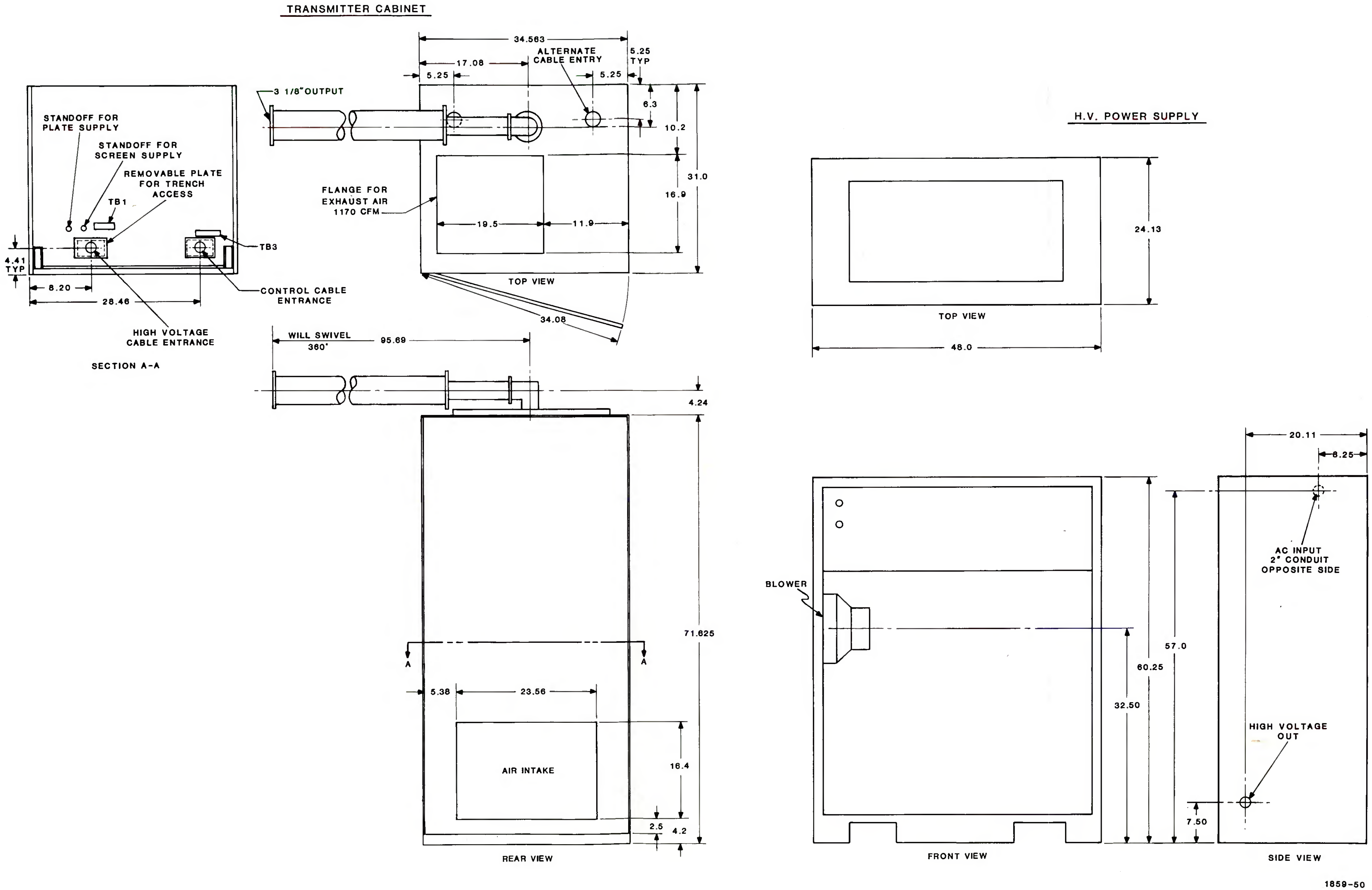


FIGURE 2-1. OUTLINE DRAWING FM-25K TRANSMITTER

2-21. Do not install the Power Amplifier tube until the installation and wiring are complete. Tube installation procedures are given in paragraph 2-31.

2-22. TRANSMITTER WIRING

2-23. Figure 2-2, Interconnecting Wiring, and figure 2-3, Primary AC Wiring, show the electrical connections to the FM-25K transmitter. Figure 2-4, Transmitter Cabinet External Connection Points, and figure 2-5, Power Supply External Connection Points, identify the physical location of the external connections.

NOTE

The FM-25K transmitter is designed to operate from a closed-delta type power source. If the service entrance to the transmitter building is an open-delta or "V-V" configuration, the local power company should be contacted and the service changed to a closed-delta configuration for proper transmitter operation. Refer to "Engineering Report, Susceptibility of the Open-Delta Connection to Third Harmonic and Transient Disturbances" in the appendix of this manual for a complete discussion.

2-24. Connect a two inch wide, 0.020 inch thick copper ground strap (not supplied) between terminal E1 in the transmitter cabinet and the ground stud in the lower front of the power supply. At a central point, bond the ground strap directly to the station earth ground connection point. It is also recommended that the customer furnished power disconnects also be bonded at some central point to the station earth ground.

2-25. TRANSMITTER CABINET TO POWER SUPPLY WIRING. The location of the control cable and high voltage cable connection points are shown in figures 2-2, 2-4, and 2-5. If it is desired to use cables of shorter length, the cables may be cut to length and terminated with the supplied crimp lugs. Connect the control and high voltage wiring as follows:

a. Connect the control cable (Harris part number 992-7804-001) from TB-3 in the transmitter cabinet to TB-1 in the power supply observing the correct wire number to terminal number as shown in figure 2-2.

b. Connect the center conductor of the RG-58 portion of the high voltage cable (Harris part number 992-7929-001) to terminal E3 in the transmitter cabinet.

c. Connect the center conductor of the RG-213 portion of the high voltage cable to terminal E2 in the transmitter cabinet.

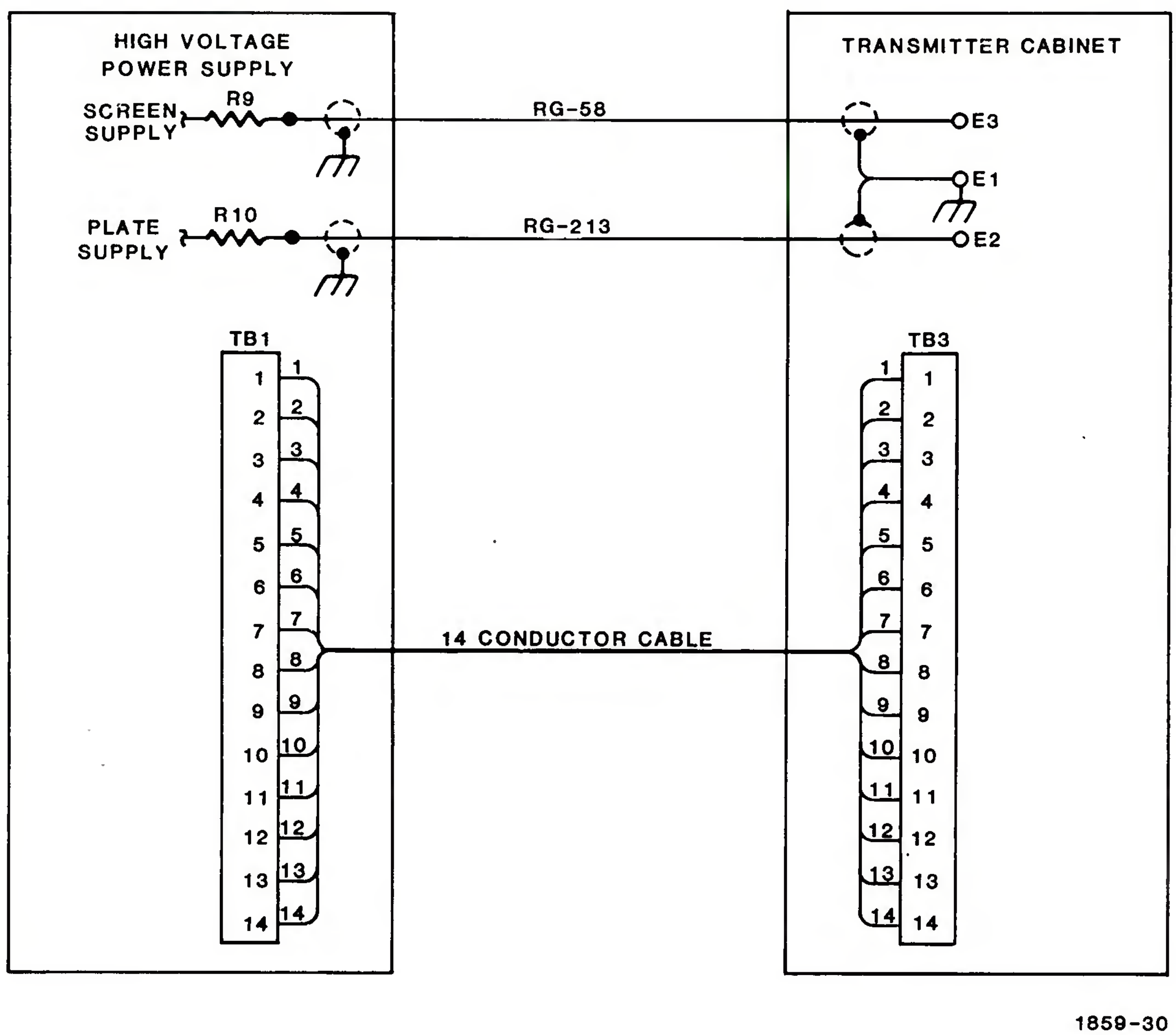
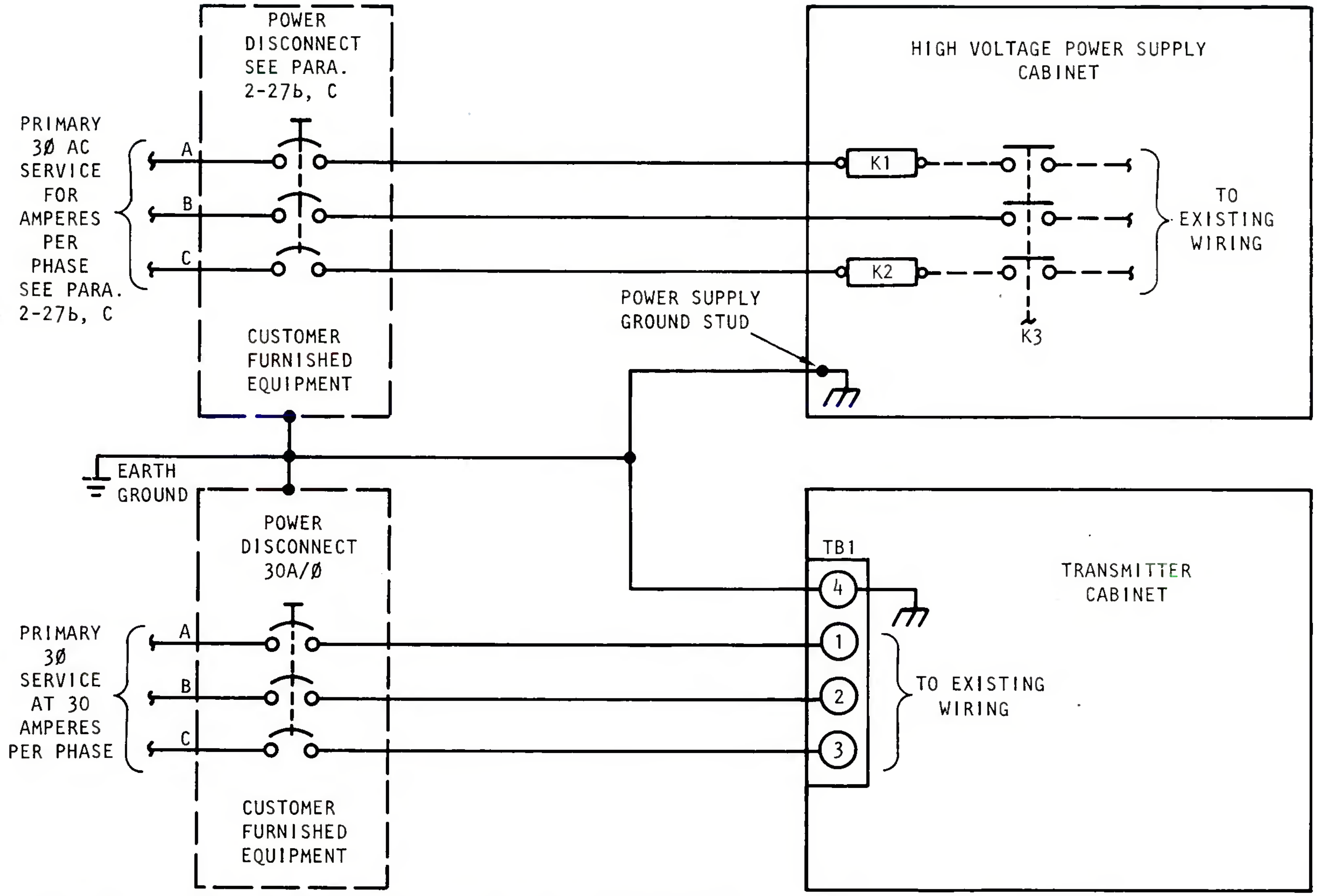


Figure 2-2. Interconnecting Wiring

WARNING: Disconnect primary power prior to servicing.



NOTES: 1. WIRE TRANSMITTER CABINET WITH NO. 10 THW WIRE.

2. WIRE HIGH VOLTAGE POWER SUPPLY CABINET WITH NO. 1/0 THW WIRE.

1859-3A

Figure 2-3. Primary AC Wiring, 3Ø, 208/240 Vac

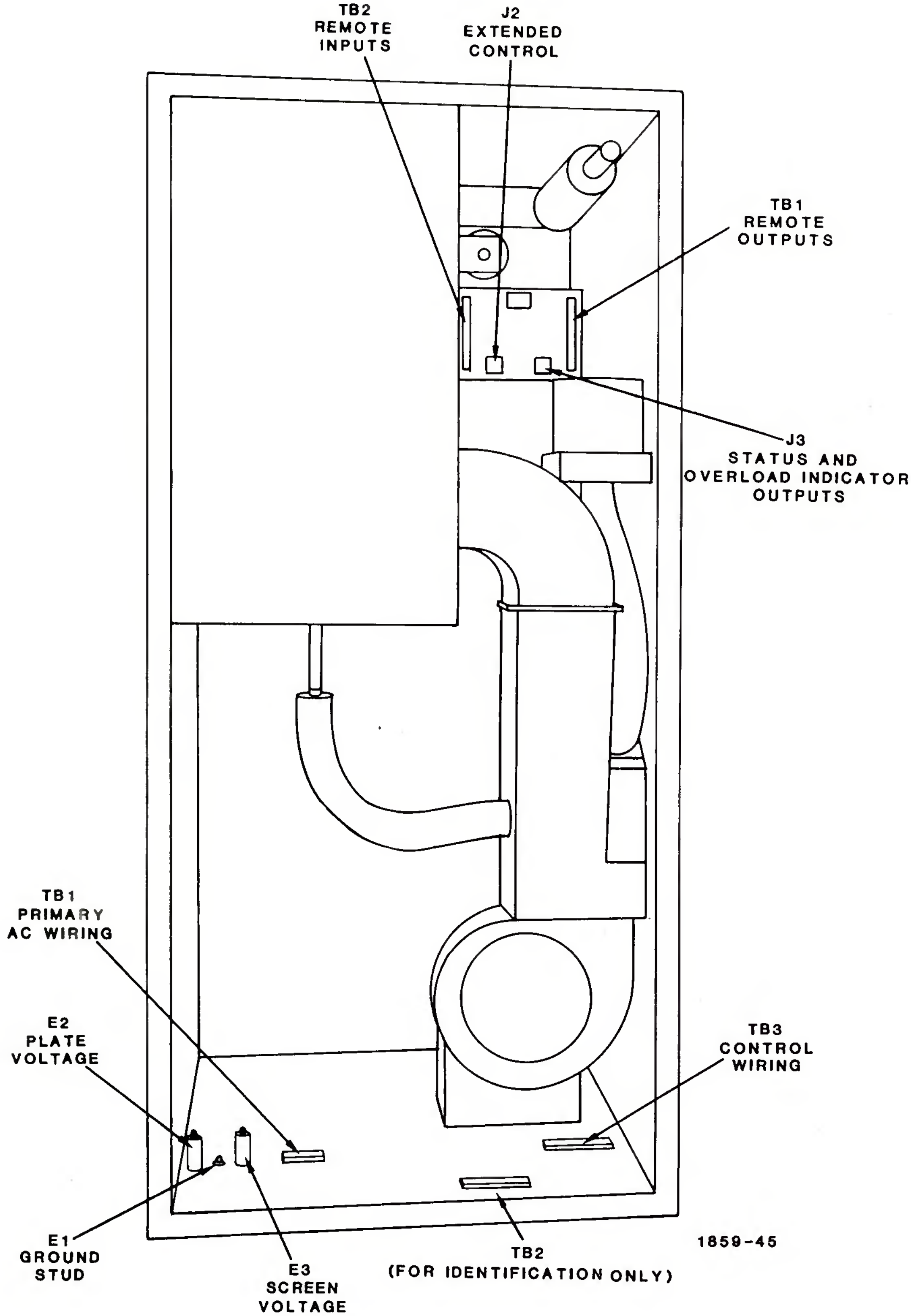


Figure 2-4. Transmitter Cabinet External Connection Points

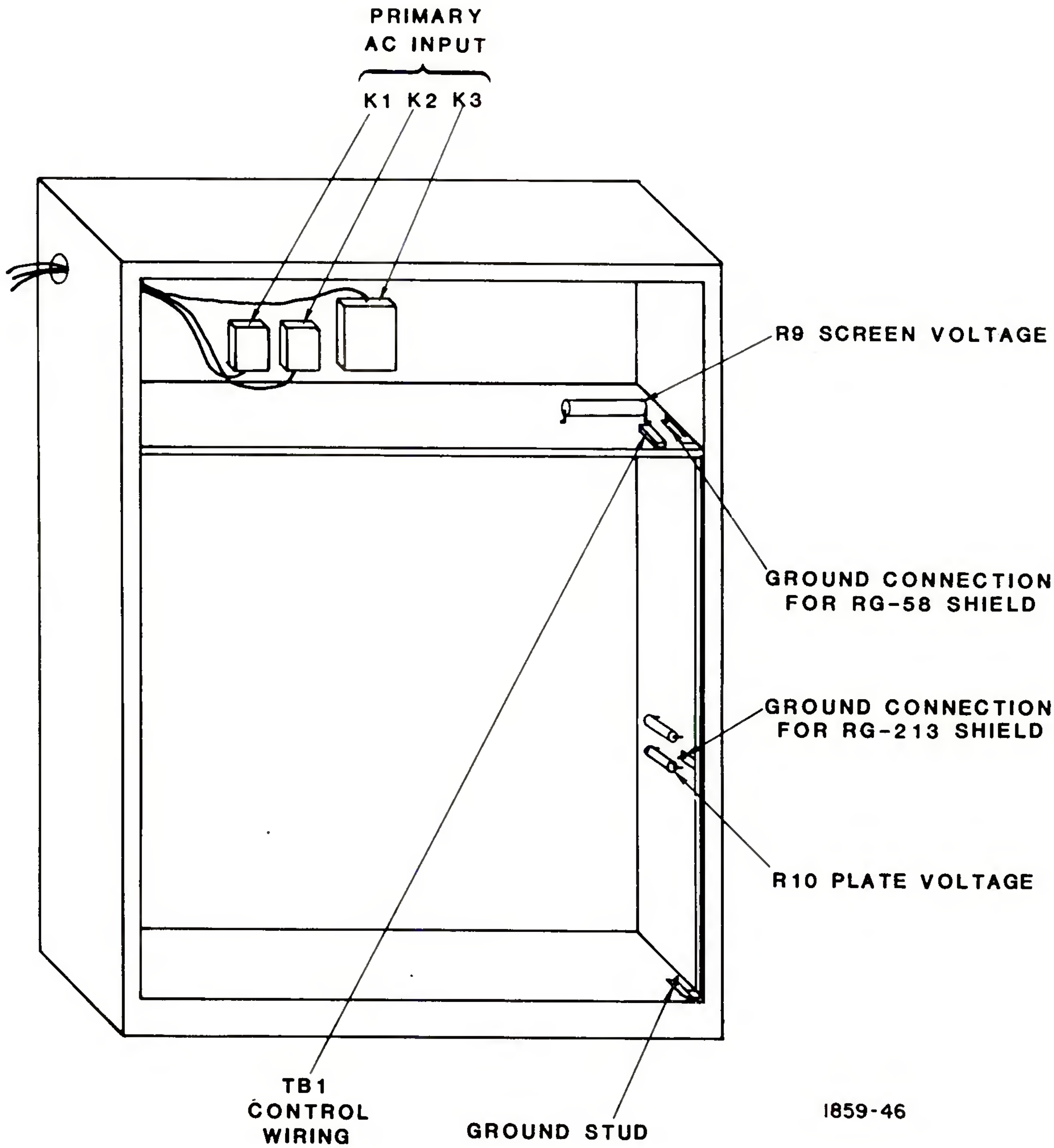


Figure 2-5. Power Supply External Connection Points

d. Connect the shields from the RG-58 and RG-213 to the ground stud E1.

e. In the power supply connect the shield of the RG-58 to the ground stud near resistor R9.

g. Connect the center conductor of the RG-58 to the open end of R9 in the power supply.

h. Connect the shield of the RG-213 to the ground stud located near resistor R10 in the power supply.

i. Connect the center conductor of the RG-213 to the open end of resistor R10 in the power supply.

CAUTION

BE SURE AND CONNECT THE SHIELDS TO GROUND SHOWN ON FIGURE 2-2 AND DRESS WIRES AWAY FROM HIGH VOLTAGE TERMINALS.

2-26. EXCITER WIRING. Connect the audio inputs and exciter remote cables to the exciter as indicated in section II of the MS-15 FM Exciter manual 888-1742-001. Exciter RF disable, AFC overload, ground, and ac power wiring has been completed at the factory and tested with the transmitter.

2-27. INPUT POWER CONNECTIONS. Refer to figures 2-3, 2-4, and 2-5 and perform the input power connections as follows:

WARNING

ENSURE THAT ALL POWER IS REMOVED WHILE PERFORMING THE FOLLOWING PROCEDURE.

CAUTION

UNLESS UNSTRUCTED TO THE CONTRARY, OVERLOAD RELAYS K1 AND K2 ARE OPERATED WITHOUT SILICONE FLUID INSTALLED IN THE DASHPOT CUP. THIS INSURES THE OVERLOAD RELAYS WILL OPERATE AT 100% VALUE OF OVERLOAD CURRENT, MUCH LIKE A FAST BLOW FUSE. SEE MANUFACTURERS DATA SHEETS FOR DETAILED RELAY OPERATION.

a. Connect the three No. 10 THW wires from the 30A power disconnect to TB1-1, -2, -3 in the transmitter cabinet.

b. For 25 kW transmitter power output, use 150 amp service for voltages up to 230 volts and 125 amp service for voltages above 230 volts.

c. For power output levels significantly less than 25 kW, size your power service according to the power consumption of your transmitter during final test. Multiply the final test line voltage by the highest 3 phase line current reading on the test data sheet multiplied by 3. This will tell you the KVA consumption. To obtain the line current for your voltage, divide the KVA consumption by the line voltage x 3. Add to this 30% for a safety margin.

2-28. OUTPUT COAX LINE INSTALLATION. Using figure 2-1 as an example or any other station layout, proceed as follows:

a. Connect the 90^{o} 3-1/8 inch elbow containing the monitor samples to the rf output port of the transmitter using the supplied 5/8 inch hardware.

WARNING

DO NOT SPLIT ANY FINGERS OF THE INTER CONDUCTOR TRANSMISSION LINE BULLETS WHEN INSERTING THE INNER CONDUCTOR.

b. Connect the end of the directional coupler assembly marked transmitter to the elbow installed in the previous step using the supplied 5/8 inch hardware.

c. Connect the low pass filter assembly to the load end of the directional coupler assembly (use the supplied hardware).

d. Terminate the low pass filter assembly with the station antenna line or station load.

2-29. MONITOR AND DIRECTIONAL COUPLER CABLES. Connect the two directional coupler cables 167 and 168 to the directional coupler. The red plug goes to the red jack. The yellow plug goes to the yellow jack on the assembly. Two monitor jacks for station monitoring equipment are provided on the elbow assembly installed in paragraph 2-28.

2-30. REMOTE CONTROL AND EXTENDED CONTROL CONNECTIONS. Tables 2-1 and 2-2 list the remote control circuit connections. Tables 2-3 and 2-4 list the extended control circuit connections. Figure 2-4 shows the physical location of the remote terminal boards and extended jacks within the transmitter cabinet. A FAILSAFE jumper must be installed between TB1-5 and TB1-12 for non-remote control operation.

Table 2-1. Remote Control Command Input Connections TB1

REMOTE CONTROL FUNCTIONS	TERMINAL BOARD CONNECTION	COMMENTS
PL OFF	TB1-1	Requires momentary +12 volts to turn plate supply off.
PL ON	TB1-2	Requires momentary +12 volts to turn plate supply on or start transmitter turn on cycle.
FIL ON	TB1-3	Requires momentary +12 volts to turn filament on.
FIL OFF	TB1-4	Requires momentary +12 volts to turn filament off or start transmitter run down cycle.
R/C	TB1-5	+12 volts present for remote control equipment when CONTROL switch is in the NORMAL position.
EXT O.L.	TB1-6	Requires momentary +12 volts for external overload input.
Interlock +12V (for dual transmitters)	TB1-7	Supplies +12V to dual transmitter interlock line.
Filament time delay (dual transmitters)	TB1-8	Supplies +12V upon completion of filament time delay for dual transmitters.
PWR UP	TB1-9	Requires continuous +12 volts to raise power.
PWR DN command	TB1-10	Requires continuous +12 volts to lower power.
GND	TB1-11	Provides ground to remote equipment.
F/S	TB1-12	Requires +12 volts while remote equipment is functioning properly.

Table 2-2. Remote Control Indicator and Metering Output Connections TB2

REMOTE CONTROL FUNCTIONS	TERMINAL BOARD CONNECTION	COMMENTS
EXT INTK	TB2-1	Removes transmitter plate voltage and illuminates EXT INTERLOCK indicator when ground applied to terminal.
Spare	TB2-2	Spare terminal available on analog board.
Spare	TB2-3	Spare terminal available on analog board.
FAULT	TB2-4	Low output, signals a FAULT.
GND	TB2-5	Provides ground to remote equipment.
PL ON	TB2-6	Open collector transistor provides ground potential through 570 ohms for remote PLATE ON status indicator.
FIL ON	TB2-7	Open collector transistor provides ground potential through 570 ohms for remote FILAMENT ON status indicator.
PLATE I	TB2-8	Provides approximately +5 volts into an open circuit for 5 amperes plate current (one volt per ampere).
VSWR	TB2-9	Provides less than 10 volts into open circuit for full scale PA VSWR reading.
PWR	TB2-10	Provides less than 10 volts into an open circuit for full scale FORWARD POWER reading.
PL V	TB2-11	Provides approximately +15 volts into an open circuit for 10 kV plate voltage.
GND	TB2-12	Provides ground to remote equipment.

Table 2-3. Extended Control Connections J2

EXTENDED CONTROL FUNCTION	JACK CONNECTION	COMMENTS
FILAMENT ON	J2-1	Open collector transistor provides ground potential through 570 ohms for extended FILAMENT ON indicator.
Power Set RAISE command	J2-2	Requires continuous +12 volts while raising power
Spare	J2-3	
FIL ON	J2-4	Requires momentary +12 volts to turn filament on.
PA P_F	J2-5	Provides less than +10 volts into an open circuit for full scale forward power metering.
PLATE ON	J2-6	Open collector transistor provides ground potential through 570 ohms for extended plate on indicator.
Power Set LOWER	J2-7	Requires continuous +12 volts while lowering power set.
FILAMENT OFF	J2-8	Requires momentary +10 volts to turn filament off or start transmitter run down cycle.
PA Ip	J2-9	Provides approximately +5 volts into open circuit for 5 amperes plate current (one volt per ampere).
Spare	J2-10	
Spare	J2-11	
Spare	J2-12	
Spare	J2-13	
Spare	J2-14	
Spare	J2-15	

Table 2-3. Extended Control Connections J2 (Continued)

EXTENDED CONTROL FUNCTION	JACK CONNECTION	COMMENTS
PLATE OFF	J2-16	Requires momentary +12 volts to turn plate supply off.
Spare	J2-17	
Spare	J2-18	
PA Ep	J2-19	Provides approximately +15 volts into an open circuit for 10 kV plate voltage.
PLATE ON	J2-20	Requires momentary +12 volts to turn plate supply on or start transmitter turn on cycle.
FAILSAFE	J2-21	Requires +12 volts to signal extended control equipment is functioning properly.
PA VSWR	J2-22	Provides less than +10 volts into open circuit for full scale PA VSWR reading.
FAULT INTLK	J2-23	Low output signals a FAULT.
GND	J2-24	Provides ground to extended control equipment.

Table 2-4. Extended Control Connections J3

EXTENDED CONTROL FUNCTION	JACK CONNECTION	COMMENTS
PA SCREEN OVER-LOAD indicator	J3-1	Provides ground potential through 1000 ohms for extended PA screen over-load indicator.
IPA VSWR OVER-LOAD indicator	J3-2	Provides ground potential through 1000 ohms for extended IPA VSWR over-load indicator.
PA VSWR OVER-LOAD indicator	J3-3	Provides ground potential through 1000 ohms for extended PA VSWR over-load indicator.
Failsafe	J3-4	Requires +12 volts while extended equipment functioning properly.
PA PLATE OVER-LOAD indicator	J3-5	Provides ground potential through 1000 ohms for extended PA PLATE overload indicator.
EXTERNAL OVER-LOAD indicator	J3-6	Provides ground potential through 1000 ohms for extended external overload indicator.
Spare	J3-7	
Ground	J3-8	Provides ground to extended equip-ment.
AFC OVERLOAD indicator	J3-9	Provides ground potential through 1000 ohms for extended overload indicator.
PLATE ON indicator	J3-10	Provides ground potential through 570 ohms for extender plate on indicator.
Spare	J3-11	
Spare	J3-12	
FILAMENT ON indicator	J3-13	Provides ground potential through 570 ohms for extended filament on indicator.

WARNING: Disconnect primary power prior to servicing.

Table 2-4. Extended Control Connections J3 (Continued)

EXTENDED CONTROL FUNCTION	JACK CONNECTION	COMMENTS
REMOTE OVERLOAD INDICATOR RESET command	J3-14	Requires momentary +12 volts to extinguish LOCAL/EXTENDED overload indicators.
Spare	J3-15	
OVERLOAD COMMON	J3-16	Provides +12 volts through reset transistor to common side (anode of LED) of extender overload indicators.
Spare	J3-17	
Spare	J3-18	
Spare	J3-19	
FAULT INTERLOCK indicator	J3-20	Provides ground for extended fault status indicator.
Spare	J3-21	
Spare	J3-22	
Ground	J3-23	Provides ground to extended equipment.
Ground	J3-24	Provides ground to extended equipment.

2-31. INITIAL PA TUBE INSTALLATION

2-32. It is recommended that the entire tube installation procedure in this section and the TUBE REMOVAL AND INSTALLATION instructions in Section V paragraph 5-49 through 5-53 be studied prior to attempting tube installation. It can not be over emphasized that improper tube installation can result in damage to the tube socket fingerstock. This is particularly important on this high frequency transmitter where the tube will not clear the plate blocking assembly and the tube socket without proper installation sequence. The PA tube is installed in the following manner:

a. Ensure all ac power is removed from the transmitter.

b. Rotate the PA TUNE control to MAX position (extreme clockwise position).

NOTE

Use the front panel control PA TUNE to place the tuning control in the maximum position.

c. Remove the PA access door held by 12 captive screws.

NOTE

Do not move the neutralization flag assembly.

d. Locate the red shipping block attached to the cavity sidewall and the plate blocking assembly.

CAUTION

PRIOR TO ATTEMPTING REMOVAL OF THE SHIPPING BLOCK, ENSURE THE TOP CLAMP (SHOWN IN FIGURE 5-2) HOLDING THE PLATE BLOCKING ASSEMBLY IN THE CAVITY SHORT IS TIGHT AND HOLDING THE BLOCKING ASSEMBLY SECURELY.

e. Remove the shipping block from inside the cavity.

f. Using an inspection mirror, examine the inside of the tube socket assembly for loose hardware or damaged fingerstock.

NOTE

The next step will determine which sequence must be used for installing the PA tube. On certain higher frequencies, the sequence in paragraph 5-53 step (c.) is the only way the tube can be installed.

g. Refer to the top pictorial of figure 5-2. On the transmitter cavity back panel locate the hardware used to mount the cavity shorting deck. Counting from the bottom set of mounting holes, determine which set of holes is being used to support the cavity shorting deck.

NOTE

If the cavity shorting deck is mounted in one of the four bottom sets of mounting holes, the sequence in paragraph 5-53 step (c.) must be used to install the tube. If the shorting deck is supported above the four bottom sets of mounting holes, the sequence in the following step (h.) may be used to install the tube.

h. The following sequence is to only be used if the cavity shorting deck is supported in mounting holes above the four bottom sets of mounting holes:

1. Holding the tube with both hands, carefully position the tube inside the cavity between the tube socket and the plate blocking assembly with the filament stem down.

2. Center the filament stem over the tube socket.

3. Gently lower the tube into the socket.

CAUTION

DO NOT ROTATE OR ROCK THE TUBE ONCE IT IS INSTALLED IN THE SOCKET OR DAMAGE WILL OCCUR TO THE FINGERSTOCK.

4. Using both hands push the tube straight down until the tube is properly seated.

NOTE

The tube socket has built in stops. Ensure the tube is all the way down in the socket and level.

5. Place the anode clamp (included in installation material) over the anode of the tube; slide the clamp down the tube and allow it to rest on the screen blocker assembly.

6. Attach the high voltage lead to the anode cap.

CAUTION

ENSURE THE PLATE BLOCKING ASSEMBLY IS BEING HELD SECURELY PRIOR TO LOOSENING THE TOP CLAMP BEFORE PROCEEDING.

7. Hold the plate blocking assembly in a secure manner, while loosening the top clamp.

8. Lower the plate blocking assembly over the tube anode until the built in stops prevent further downward motion.

9. Refer to figure 5-2. Rotate the plate blocking assembly on the tube until the edge of the stationary tuning plate is parallel to the same cavity wall where the front panel adjustable tuning plate is mounted.

10. Ensure the top clamp is over the fingerstock protruding from the cavity short.

11. Tighten the top clamp.

12. Lift the anode clamp off the screen blocker assembly and slide the clamp over the fingerstock at the bottom edge of the plate blocking assembly.

13. Tighten the anode clamp ensuring the clamp is securing the blocking assembly to the tube anode.

i. Ensure all loose hardware and shipping material is removed from inside the cavity.

j. Install the PA access door using the captive hardware.

2-33. Install the side panels and rear door on the transmitter cabinet. Install the panels on the High Voltage Power Supply. This completes the installation and wiring of the FM-25K transmitter.

2-34. INITIAL CHECKOUT

2-35. INSTALLATION CHECKOUT. The checkout procedures to be performed prior to intial turn-on are as follows:

a. Ensure that the following circuit breakers and switches are set to OFF.

   1. Station power distribution breaker to the high voltage power supply.

   2. Station power distribution breaker to the transmitter cabinet.

   3. Both circuit breakers on the high voltage power supply.

   4. The four circuit breakers on the transmitter front panel.

b. Ensure that all equipment removed from the transmitter for shipment, including the power amplifier tube, has been installed; verify wiring connections using the wiring diagrams.

c. Ensure that all installation wiring is correctly installed.

d. Ensure that both grounding hooks are in the proper holders.

e. Ensure that the transmitter rf output is terminated into the station antenna or load with a known good VSWR.

f. Ensure that all remote control and extended control equipment is disconnected or in a stand-by mode to prevent accidental override of local control.

g. On the transmitter front panel, set the CONTROL switch to the LOCAL ONLY position.

h. Set the ON-OFF switch behind the swing down panel on the MS-15 Exciter to ON.

i. Remove the output amplifier from the MS-15 Exciter.

WARNING

230 VAC IS NOW PRESENT IN THE TRANSMITTER CABINET AND THE HV POWER SUPPLY CABINET CONTROLS.

j. Open the transmitter cabinet rear door and using a VOM on the 250 Vac scale verify the correct voltage and all three phase are present on terminal board TB1-1, -2, and -3.

k. Set the station power distribution circuit breaker that supplies power to the transmitter cabinet to ON.

l. Close the transmitter cabinet rear door.

m. Set the BIAS circuit breaker to ON and verify the following indicators are illuminated.

   1. REG DC +12V and -12V.

   2. CONTROL LOCAL ONLY.

   3. AIR INTERLOCK.

   4. Possibly the FAULT INTERLOCK.

n. Depress the FILAMENT ON pushbutton.

o. Momentarily set the BLOWER circuit breaker to ON and return it to OFF; verify that the blower motor is rotating in the correct direction.

CAUTION

IF THE BLOWER IS NOT ROTATING IN THE CORRECT DIRECTION, REMOVE ALL POWER AND REVERSE ANY TWO OF THE THREE INPUT WIRES CONNECTED TO TB1.

p. Set the BLOWER circuit breaker to ON; let the blower build up speed.

NOTE

When the AIR INTERLOCK indicator extinguishes the filament contactor should be heard energizing and the FILAMENT ON indicator should illuminate. If the AIR INTERLOCK indicator fails to extinguish, refer to paragraph 5-41 AIR SWITCH ADJUSTMENT to properly set the air switch.

q. Depress the FILAMENT OFF pushbutton; the filament contactor should be heard deenergizing and the FILAMENT ON indicator should extinguish.

r. Verify that the blower continues to rotate for approximately three minutes, then turns off.

s. Depress the FILAMENT ON pushbutton.

CAUTION

ENSURE THAT THE STATION CIRCUIT BREAKER PROVIDING POWER TO THE HIGH VOLTAGE POWER SUPPLY IS OFF.

t. After approximately 20 seconds, depress the PLATE ON pushbutton; the contactors in the High Voltage Power Supply should be heard energizing and the PLATE ON indicator illuminates.

u. Depress the PLATE OFF pushbutton; verify that the contactors in the High Voltage Power Supply deenergize and the PLATE on indicator extinguishes.

2-36. INTERLOCK CHECKOUT. Perform the interlock checkout as follows:

a. Depress the PLATE ON pushbutton; verify the PLATE ON indicator illuminates.

b. Open the transmitter cabinet rear door; verify that the blower stops, the FILAMENT ON and PLATE ON indicators extinguish, the contactors in the High Voltage Power Supply deenergize, and the XMTR CAB INTERLOCK indicator illuminates.

c. Depress the PLATE ON pushbutton with the rear door open; verify that the transmitter status remains the same as in step b.

d. Close the rear door; the XMTR CAB INTERLOCK indicator should extinguish, the blower should start, and the FILAMENT ON indicator should illuminate.

NOTE

PLATE ON indicator should not illuminate again until the PLATE ON pushbutton is depressed.

e. Remove the front upper panel from the High Voltage Power Supply.

WARNING

AC VOLTAGE IS PRESENT IN THE HV POWER SUPPLY WHEN THE TRANSMITTER CABINET HAS AC VOLTAGE APPLIED.

f. Depress the PLATE ON pushbutton; PLATE ON indicator should remain extinguished.

g. Remove the grounding hook in the upper compartment of the power supply and temporarily replace the upper panel removed in step e.

h. Depress the PLATE ON pushbutton; PLATE ON indicator should illuminate, but the High Voltage contactor and the shorting solenoids should remain in a de-energized condition.

i. Replace the grounding hook and secure the upper panel on the power supply.

j. Repeat steps e. through i. using the lower front panel on the power supply.

k. Operate any external interlock to ensure proper operation; verify that the EXT INTERLOCK indicator illuminates and the PLATE ON indicator remains extinguished when the PLATE ON pushbutton is depressed.

2-37. EXCITER AND IPA CHECKOUT. Perform the Exciter and IPA checkout as follows:

a. Depress the PLATE OFF pushbutton; PLATE OFF indicator extinguishes.

b. Set the IPA circuit breaker to ON.

c. Depress the PLATE ON pushbutton; verify the presence of approximately 33 Vdc at the test points (+ VOLTS and GND) located immediately below the IPA circuit breaker using a VOM set to the 50 Vdc scale.

NOTE

In the next step ensure the negative lead of the VOM is connected to the GRD test point and the positive lead of the VOM is connected to the V REG test point.

d. Verify the presence of voltage at the test points on the four IPA AMP Modules and the IPA DRIVER Module.

NOTE

The voltage measured at the module test points will vary from transmitter to transmitter, but the voltage between modules should not vary more than 0.1 volt.

e. Depress the PLATE OFF pushbutton; the PLATE ON indicator extinguishes.

f. Install the RF Amp module in the MS-15 Exciter.

2-38. The IPA checkout procedure in this paragraph requires the use of a 50 ohm load capable of dissipating 500 watts. If the station does not have such a load available proceed to paragraph 2-39. The rf output of the IPA may be checked in the following manner:

a. Open the transmitter cabinet rear door.

b. Disconnect the RG-213 coax cable at the IPA low pass filter output.

c. Route a piece of temporary RG-213 cable through the top of the cabinet and connect it to the low pass filter output.

d. Connect the other end of the temporary RG-213 cable to a 50 ohm load capable of dissipating 500 watts.

e. Close the transmitter cabinet rear door.

f. Rotate the IPA OUTPUT PWR ADJ control to the extreme counter-clockwise position.

g. On the MS-15 Exciter RF AMP module rotate the OUTPUT ADJUST control to the extreme counterclockwise position.

h. Rotate the IPA POWER meter switch to the FORWARD POWER position.

i. Depress the MS-15 Exciter MULTIMETER FWD PWR pushbutton.

j. Depress the FILAMENT ON pushbutton. After 20 seconds, depress the PLATE ON pushbutton; PLATE ON indicator illuminates.

k. While monitoring the MS-15 Exciter MULTIMETER, rotate the Exciter OUTPUT ADJUST until the MULTIMETER indicates 10 watts; verify that the IPA POWER meter indicates approximately 100 watts (approximately 10 dB gain). The RFA and RFB indicators should be illuminated on the IPA DRIVER module.

l. Depress the Exciter MULTIMETER REF PWR pushbutton; verify the MULTIMETER indicates approximately one watt or less.

m. Rotate the IPA POWER meter switch to the REFLECTED POWER position; verify a low reflected power.

n. Rotate the IPA POWER meter switch to the FORWARD POWER position.

o. Rotate the IPA OUTPUT PWR ADJ clockwise until the IPA POWER meter indicates 350 watts; verify that the RFA and RFB indicators are illuminated on all five IPA Modules.

p. Rotate the IPA OUTPUT PWR ADJ control and the Exciter OUTPUT ADJ to their extreme counterclockwise positions.

q. Depress the FILAMENT OFF pushbutton; the PLATE ON and FILAMENT ON indicators extinguish.

r. Open the transmitter cabinet rear door; remove the temporary RG-213 cable from the low pass filter output.

s. Reconnect the original RG-213 cable to the low pass filter output; close the rear door.

2-39. POWER AMPLIFIER CHECKOUT. The following text provides the checkout procedure for the FM-25K PA stage.

2-40. Power Amplifier Neutralization. The FM-25K transmitter requires neutralization with no power applied. An rf indicator device of some type is required. The following list of test equipment is in order of preference, but neutralization may be accomplished using any one of the devices listed.

a. RF Spectrum Analyzer

b. RF Voltmeter

c. 100 mHz oscilloscope

d. VTVM with RF probe

Select one of the listed pieces of test equipment and neutralize the power amplifier as follows:

a. Set the station power distribution breaker to the High Voltage Power Supply to OFF.

b. Set the station power distribution breaker to the transmitter cabinet to OFF.

c. Set the MS-15 Exciter POWER switch to OFF and rotate the Exciter OUTPUT ADJ control to its extreme counterclockwise position.

d. Open the transmitter cabinet rear door.

e. Disconnect the RG-58 cable from the exciter RF OUTPUT terminal J3.

f. Disconnect the RG-213 cable from the input terminal to the power amplifier cavity.

g. Connect a temporary RG-58 cable to the Exciter RF OUTPUT terminal J3.

h. Connect the other end of the temporary RG-58 cable to the power amplifier cavity input.

i. Disconnect the ac power plug from the Exciter AC POWER jack J2.

j. Connect the Exciter test cord (Harris part number 929-2816 001) into AC POWER jack J2.

k. Connect the other end of the test cord to a 110 Vac source.

l. Loosen the 12 captive screws on the PA access panel and remove the panel.

m. Using figure 2-7 as a reference connect a temporary short of copper strap or jumper wire between the bottom of the rod supporting the neturalizing flag and the PA deck.

n. Connect the selected rf indicating device to one of the monitor samples located on the swivel elbow on the top of the transmitter.

o. Set the Exciter POWER switch to ON.

p. Depress the Exciter MULTIMETER FWD PWR pushbutton.

q. Rotate the Exciter OUTPUT ADJ control clockwise until the MULTIMETER indicates 10 watts.

r. Depress the MULTIMETER REF PWR pushbutton and adjust the power amplifier INPUT TUNE and GRID TUNE controls for minimum indication on the Exciter MULTIMETER.

s. Monitor the rf sampling device connected in step n. and adjust the power amplifier PA LOAD and PA TUNE controls for maximum indication.

t. Temporarily place the PA access door over the access port as shown by the dotted lines in figure 2-7.

u. Remove the temporary short from the neutralizing flag and adjust the INPUT TUNE and GRID TUNE controls for minimum indication on the Exciter MULTIMETER.

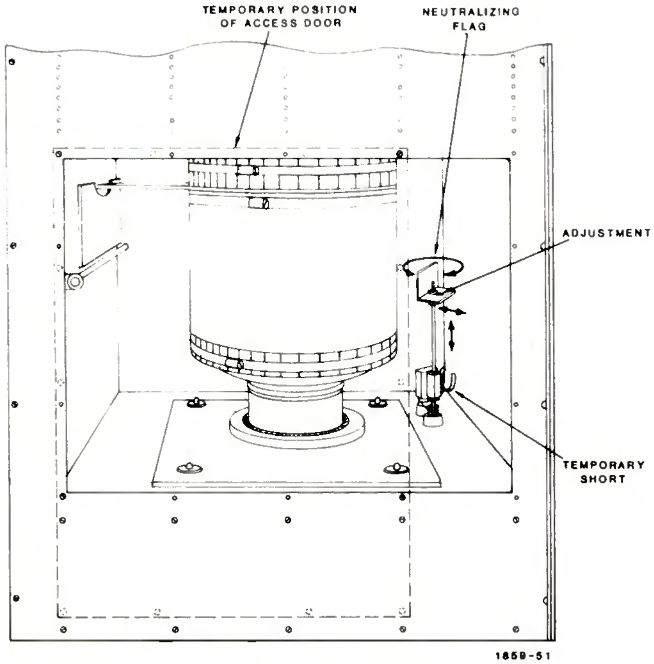


Figure 2-7. FM-25K Neutralizing Flag

NOTE

If the rf indicating device displays the rf signal down by -30 dB or more with the short removed as compared to with the short in place, no further adjustment is required. If the signal is not -30 dB down further adjustment is required.

v. Adjust the neutralizing flag for minimum indication on the rf indicating device.

NOTE

As shown in figure 2-7 the neutralizing flag may be adjusted in three planes. The nuts holding the flag must be loosened prior to movement of the flag. The transmitter has been neutralized at the factory with the tube that was shipped with the transmitter. Initial adjustment should only require movement of the flag within the adjustment slot.

w. Replace the PA access door in the normal position and secure with the 12 captive screws.

x. Rotate the Exciter OUTPUT ADJ control to the extreme counter-clockwise position.

y. Set the Exciter POWER switch to OFF.

z. Disconnect the Exciter test cord and reconnect the original cable to AC POWER jack J2.

aa. Disconnect the temporary RG-58 cable between the Exciter RF OUT- PUT jack J3 and the cavity input.

ab. Connect the original RG-58 cable to the RF OUTPUT jack J3.

ac. Connect the original RG-213 cable to the cavity input.

ad. Disconnect the rf indicator device from the monitor sample. This completes the neutralization procedure.

2-44. High Voltage and RF Checkout. The following procedure is to be used in the initial high voltage checkout:

a. Ensure that the following circuit breakers and switches are set to OFF.

1. Station power distribution breaker to the High Voltage Power Supply.

2. Station power distribution breaker to the transmitter cabinet.

3. Both circuit breakers on the High Voltage Power Supply.

4. The four circuit breakers on the transmitter front panel.

5. The Exciter POWER ON switch behind the swing down panel.

WARNING

ENSURE ALL POWER IS REMOVED FROM THE TRANSMITTER AND HIGH VOLTAGE POWER SUP-PLY. USE THE SHORTING STICK TO GROUND ALL CAPACITORS AND TERMINALS BEFORE OPERATING THE HIGH/LOW VOLTAGE SWITCH.

b. Remove the lower front panel of the High Voltage Power Supply.

c. Set the HIGH/LOW plate voltage switch to the LOW voltage position. (Refer to figure 3-3 for physical location of the switch.)

d. Install the lower front panel of the High Voltage Power Supply.

e. Set the BIAS and BLOWER breakers to ON. Set the POWER OUT control to the MANUAL position. Set the PA TUNE, PA LOAD, GRID TUNE, and INPUT TUNE controls to the values indicated on the factory test data sheet.

f. Depress the FILAMENT ON pushbutton; the FILAMENT ON indicator illuminates.

g. Rotate the MULTIMETER switch to the BIAS VOLTAGE position; verify the presence of grid bias voltage.

h. Adjust the GRID VOLTS ADJ control until the MULTIMETER indicates the same voltage recorded on the factory test data sheet.

i. Depress the FILAMENT OFF pushbutton; FILAMENT ON indicator extinguishes.

j. Set the FILAMENT circuit breaker to the ON position.

k. Depress the FILAMENT ON pushbutton; FILAMENT ON indicator illuminates.

l. Rotate the MULTIMETER switch to the FILAMENT VOLTAGE position; verify the presence of filament voltage.

m. Adjust the FILAMENT ADJ control until the MULTIMETER indicates the same voltage as recorded on the factory test data sheets.

n. Depress the FILAMENT OFF pushbutton; the MULTIMETER indication drops to zero.

o. Set the station power distribution breaker to the High Voltage Power Supply to ON.

p. Set the BLOWER and SCREEN circuit breakers on the High Voltage Power Supply to ON.

q. Rotate the MULTIMETER switch to the SCREEN VOLTAGE position.

r. Depress the FILAMENT ON pushbutton; the FILAMENT ON indicator illuminates.

s. Depress the PLATE ON pushbutton; verify that the PLATE VOLTAGE meter indicates approximately 4700 volts, the PLATE CURRENT meter has no indication, and the MULTIMETER indicates screen voltage present.

NOTE

The screen voltage should be approximately the same as on the factory test data sheets. Screen voltage is adjusted by using the POWER OUT RAISE/LOWER control.

t. Depress the PLATE OFF pushbutton.

u. Rotate the OUTPUT ADJ control on the Exciter and the IPA OUTPUT PWR ADJ control to their extreme counterclockwise positions.

v. Set the Exciter POWER switch to the ON position.

w. Depress the PLATE ON pushbutton.

x. Depress the Exciter MULTIMETER FWD PWR pushbutton.

y. Rotate the OUTPUT ADJ control on the Exciter until the Exciter MULTIMETER indicates approximately 5 watts; verify the IPA POWER meter indicates approximately 50 watts.

z. Rotate the IPA POWER meter switch to the REFLECTED POWER position; adjust INPUT TUNE and GRID TUNE controls for minimum indication on the IPA POWER meter.

aa. Rotate the POWER meter switch to the FORWARD position; adjust the PA TUNE and PA LOAD controls for maximum power indication on the POWER meter.

ab. Momentarily rotate the POWER meter switch to the REFLECTED position; verify a low VSWR indication then return the switch to the FORWARD position.

ac. Rotate the Exciter OUTPUT ADJ until the Exciter MULTIMETER indicates 10 watts forward; readjust the INPUT TUNE and GRID TUNE for minimum REFLECTED POWER on the IPA POWER meter.

ad. Again adjust the PA TUNE and PA LOAD as in step aa.

ae. Proceed with the low voltage tune-up by rotating the IPA OUTPUT ADJ control in small increments until the IPA FORWARD POWER indicates 350 watts. With each increase in IPA FORWARD POWER adjust the INPUT TUNE and GRID TUNE for minimum IPA REFLECTED POWER and the PA TUNE and PA LOAD controls for maximum FORWARD power on the POWER meter.

NOTE

With the power supply at half tap voltage the gain of the PA is approximately 15 dB. The maximum power out of the PA tube with half voltage should be approximately 10 kW. The PLATE CURRENT will be approximately 3 amp. The PA efficiency will be approximately of 70 percent.

af. Depress the FILAMENT OFF pushbutton; let the transmitter complete its cool down cycle.

ag. Set the station power distribution breakers to the High Voltage Power Supply and to the transmitter cabinet to OFF.

WARNING

ENSURE ALL POWER IS REMOVED FROM THE TRANSMITTER AND THE HIGH VOLTAGE POWER SUPPLY. USE THE SHORTING STICK TO GROUND ALL CAPACITORS AND TERMINALS BEFORE OPERATING THE HIGH/LOW VOLTAGE SWITCH.

ah. Carefully remove the lower front panel of the High Voltage Power Supply; use the shorting stick to ground out all capacitors and terminals.

ai. While grounding the HIGH/LOW VOLTAGE switch with the shorting stick, change the switch to the HIGH position.

aj. Replace the shorting stick in its holder; replace the lower front panel of the High Voltage Power Supply.

ak. Set the station power distribution breakers to the transmitter cabinet and the High Voltage Power Supply to ON.

al. Rotate the Exciter OUTPUT ADJ control and the IPA OUTPUT PWR ADJ control to their extreme counterclockwise position.

am. Depress the FILAMENT ON pushbutton; FILAMENT ON indicator illuminates.

an. Rotate the MULTIMETER switch to the SCREEN VOLTAGE position.

ao. After approximately 20 sconds, depress the PLATE ON pushbutton; verify the PLATE VOLTAGE meter indicates approximately 9400 volts and the PLATE CURRENT meter has no indication.

ap. Set the POWER OUT switch to the MANUAL position. Using the RAISE/LOWER POWER OUT switch adjust the MULTIMETER SCREEN VOLTAGE indication to the same as recorded in the factory test data sheets.

NOTE

During the high power tune up procedure the screen voltage will have to be readjusted as more power is produced by the transmitter. Follow step ap. in readjusting the screen voltage.

aq. Repeat steps x. through af. and tune the transmitter for full operating power output and the required efficiency. Compare the final operating parameters to the factory test data.

ar. This completes the initial High Voltage and RF checkout.

2-45. Automatic Power Control Set-Up. The automatic power control in the FM-25K transmitter may be set-up in the following manner.

a. Depress the FILAMENT OFF pushbutton; let the transmitter complete the rundown cycle.

b. Remove all ac power from the transmitter.

c. Remove the Analog Board from the Controller.

d. Select either 2% or 4% power range and place jumper P1 into the correct jacks.

NOTE

P1 plugs into J1 and J2 for the 2% range and P1 plugs into J2 and J3 for the 4% range.

e. Reinstall the Analog Board in the Controller.

f. Restore ac power to the transmitter.

g. Set the POWER OUT control to the MANUAL position.

h. Bring the transmitter up to full operating power.

i. Verify that the screen voltage is at midrange when the transmitter is at 100% operating power. If not retune the transmitter so that 100% operating power and the screen voltage midrange occur at the same time. The factory test data sheets should be used as a guide for the initial dial settings.

j. Observe the AUTO PWR RAISE and LOWER indicators.

k. Use the POWER SET RAISE/LOWER control to extinguish both the AUTO POWER RAISE/LOWER indicators.

NOTE

> If the AUTO POWER RAISE indicator is illuminated depress POWER SET control to the LOWER position until the RAISE indicator is extinguished. Conversely if the AUTO POWER LOWER indicator is illuminated depress the POWER SET control to the RAISE position until the LOWER indicator is extinguished.

l. When both the AUTO POWER RAISE and the AUTO POWER LOWER indicators are extinguished set the POWER OUT control to the AUTO position.

m. This completes the automatic power control set-up.

2-46. Remote Control Set-Up. The FM-25K transmitter is compatible with remote systems available from TFT, Moseley, and Harris. The user is refered to the appropriate vendor instruction manual.

SECTION III

OPERATION

3-1. INTRODUCTION

3-2. This section contains operation procedures and information pertaining to identification, location, and function of the controls and indicators on the FM-25K transmitter.

3-3. CONTROLS AND INDICATORS

3-4. Figures 3-1 through 3-3 show the location of all FM-25K controls and indicators. Tables 3-1 through 3-3 list all controls and indicators with the function of each item listed.

3-5. Controls and indicators for the exciter are described in the exciter publication.

3-6. OPERATION

3-7. The following operational procedure is presented for an FM-25K under the assumption that the transmitter has been thoroughly and properly aligned and is free of any discrepancies. Visually inspect the cabinet to ensure that no foreign objects are inside, all parts and components are properly installed, all connectors are secure, and all interlocks are closed.

3-8. TRANSMITTER TURN ON

3-9. Set the FM exciter POWER ON/OFF switch to ON.

3-10. Depress the PLATE ON switch. The exciter POWER indicator will illuminate and the AIR INTERLOCK indicator will illuminate.

3-11. As the blower comes up to speed, the AIR INTERLOCK indicator will go out and the FILAMENT ON indicator will illuminate.

3-12. Operate the multimeter switch to FILAMENT VOLTAGE and adjust the FILAMENT ADJ control as required to obtain the correct filament voltage indication.

3-13. After a delay of 20 seconds to allow the PA filament to heat, the PLATE ON indicator will illuminate and the IPA RFA/RFB indicators will illuminate.

3-14. Note the PLATE CURRENT meter indication to ensure the PA plate circuit is correctly resonated.

3-15. Operate the FORWARD/RELFECTED switch to FORWARD. Note the transmitter RF output power. If adjustment is required, proceed as follows:

a. Operate the IPA REFLECTED POWER/FORWARD POWER switch to FORWARD POWER. If required, adjust the IPA OUTPUT POWER ADJ control to establish the correct IPA stage power output.

b. Operate the FORWARD/REFLECTED POWER switch to FORWARD. Adjust the transmitter power output power by tuning and loading to achieve the rated output power.

3-16. Operate the FORWARD/REFLECTED POWER switch to REFLECTED and note the VSWR. The transmitter will operate into a 1.7:1 maximum mismatch, however the antenna VSWR should be kept to a minimum level. If a high VSWR is present, the cavity may not be brought to resonance with only the PLATE TUNE control. If cavity resonance cannot be achieved, the PLATE TUNE control will be at either extreme (MIN or MAX). COARSE tuning of the cavity must be made. If the PLATE TUNE control is at MAX, the COARSE tuning short of the cavity needs to be lowered. If the PLATE TUNE control is at MIN, the COARSE tuning short of the cavity needs to raised.

3-17. The IPA stage power output is equal to the IPA POWER meter indication minus the IPA POWER meter reflected power indication. Table 3-4 lists VSWR levels corresponding to various reflected power levels. The index of the table is obtained by dividing the IPA stage reflected power indication in watts by the IPA stage forward power indication in watts.

3-18. TRANSMITTER TURN OFF

3-19. Depress the FILAMENT OFF switch. Operation of the transmitter will cease, however the blower will operate for approximately 3.5 minutes to ensure adequate cooling of the PA stage.

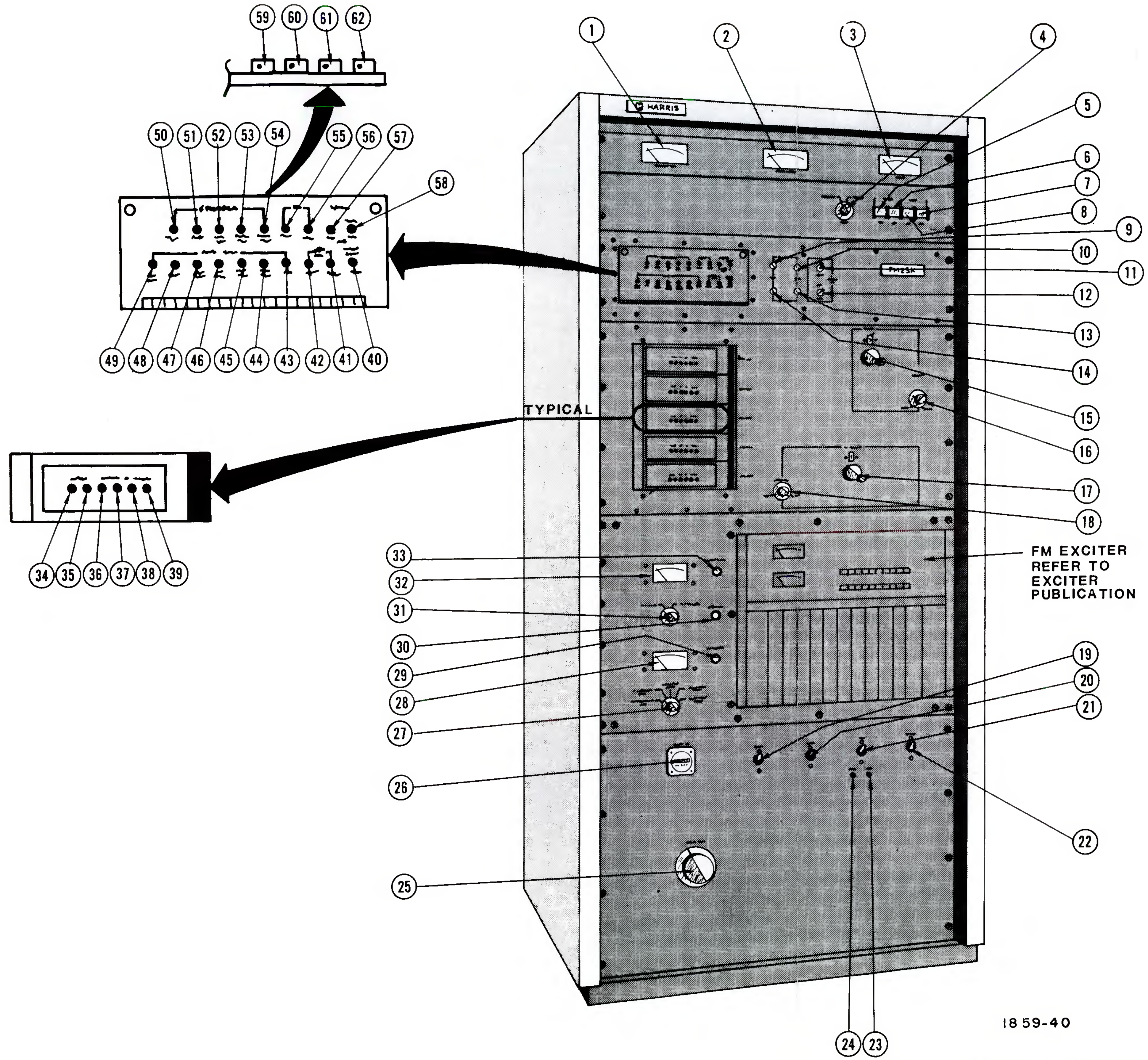


FIGURE 3-1. CONTROLS & INDICATORS FRONT

Table 3-1. Controls and Indicators, Front

REF.	CONTROL/INDICATOR	FUNCTION
1	PLATE VOLTAGE meter (M4)	Displays PA plate voltage.
2	PLATE CURRENT meter (M5)	Displays the PA stage plate current.
3	POWER meter (M6)	Displays VSWR or transmitter RF output as selected by the FORWARD/REFLECTED POWER switch.
4	FORWARD/REFLECTED POWER switch (S11)	Selects between a POWER meter display of VSWR or transmitter RF output.
5	FILAMENT ON switch (S1)	Applies power to all circuits except the PA plate and screen power supplies. Indicator illuminates when command signal is applied to the filament contactor.
6	FILAMENT OFF switch (S4)	Turns off all RF power related circuits. Blower rundown cycle initiates.
7	PLATE OFF switch (S3)	Turns the PA plate and screen power supplies off.
8	PLATE ON switch (S2)	Energizes the PA plate and screen power supplies. Indicator illuminates when the command signal is applied to plate contactor.
9	FWD PA PWR CAL control (R4)	Allows calibration of the POWER meter when the POWER switch is in the FORWARD position (FACTORY CALIBRATED).
10	REFLD PA PWR CAL control (R5)	Allows calibration of the POWER meter when the POWER switch is in the REFLECTED position (FACTORY CALIBRATED).
11	POWER OUT AUTO/MANUAL switch (S1)	Allows selection of either manual or automatic control of the transmitter RF output level.

Table 3-1. Controls and Indicators, Front (Continued)

REF.	CONTROL/INDICATOR	FUNCTION
12	POWER OUT RAISE/ LOWER switch (S2)	Adjusts the transmitter RF output by controlling the motorized screen potentiometer.
13	REFLD IPA PWR CAL control (R3)	Allows calibration of the IPA POWER meter reflected power indication (FACTORY CALIBRATED).
14	FWD IPA PWR CAL control (R2)	Allows calibration of the IPA POWER meter forward power indication (FACTORY CALIBRATED).
15	PA LOAD control and cyclometer (C16)	Adjusts coupling of the PA CAVITY RF output to the antenna.
16	PA TUNE MIN/MAX control (C_t)	Adjusts tuning of the PA CAVITY plate circuit.
17	GRID TUNE control and cyclometer (L4)	Adjusts tuning of the PA stage grid circuit.
18	INPUT TUNE MIN/MAX control (C9)	Adjusts coupling of the IPA RF output to the PA stage.
19	FILAMENT circuit breaker (CB1)	Provides control and overload protec-tection for the PA filament supply.
20	BIAS circuit breaker (CB2)	Provides control and overload protection for the FM exciter and control grid power supplies, and the logic power supply.
21	IPA circuit breaker (CB3)	Provides control and overload protection for the IPA power supply.
22	BLOWER circuit breaker (CB4)	Provides control and overload protection for the blower circuitry.
23	GRD test point (TP2	Chassis ground.
24	+VOLTS test point (TP2)	Allows measurement of the IPA unregulated power supply output voltage.

WARNING: Disconnect primary power prior to servicing.

Table 3-1. Controls and Indicators, Front (Continued)

REF.	CONTROL/INDICATOR	FUNCTION
25	FILAMENT ADJ control (T2)	Adjusts the PA filament voltage.
26	FILAMENT HRS meter (M1)	Indicates hours of PA filament operation.
27	Multimeter switch (S10)	Selects between a MULTIMETER indication of filament voltage, bias voltage, bias current, screen voltage, or screen current.
28	MULTIMETER (M2)	Indicates filament voltage, bias voltage, bias current, screen voltage current, or screen current as selected by the multimeter switch.
29	BIAS VOLTS ADJ control (R8)	Adjusts the bias voltage applied to the PA tube control grid.
30	HUM NULL control (R33)	Adjusts the ac signal placed on the PA tube control grid to balance out hum caused by filament emission.
31	IPA REFLECTED POWER/ FORWARD POWER switch (S12)	Selects between an IPA power meter display of IPA stage forward or reflected power.
32	IPA POWER meter (M3)	Displays IPA stage forward or reflected power.
33	IPA OUTPUT PWR ADJ control (R31)	Adjusts the RF output of all IPA stage amplifier modules simultaneously.
34	RFA test point (TP4)	Allows measurement of a dc potential representative of module amplifier A RF output.
35	RFA indicator (DS2)	Indicates module amplifier A RF output is 20 watts or greater when illuminated.
36	GRD test point (TP3)	Module ground.

Table 3-1. Controls and Indicators, Front (Continued)

REF.	CONTROL/INDICATOR	FUNCTION
37	VREG test point (TP2)	Allows measurement of the module regulated dc transistor amplifier collector voltage with an external meter.
38	RFB indicator (DS1)	Indicates module amplifier B RF output is 20 watts or more when illuminated.
39	RFB test point (TP1)	Allows measurement of a dc potential representative of module amplifier B RF output.
40	PWR SET RAISE/LOWER switch (S2)	Adjusts the RF power output reference level when operating in automatic control.
41	AUTO PWR LOWER indicator (DS14)	When illuminated, indicates the RF power must be lowered to equalize the transmitter RF power output with the reference level established with the PWR SET RAISE/LOWER switch. This function will be completely automatic if the POWER OUT AUTO/MANUAL switch is in the AUTO position.
42	AUTO PWR RAISE indicator (DS13)	When illuminated, indicates RF power must be raised to equalize the transmitter RF power output with the reference level established with the PWR SET RAISE/LOWER switch. This function will be completely automatic if the POWER OUT AUTO/MANUAL switch is in the AUTO position.
43	EXT OVERLOAD indicator (DS11)	Indicates the external overload has triggered the external overload circuit when illuminated.
44	PA PLT OVERLOAD indicator (DS10)	Indicates excessive PA plate current has triggered the PA plate overload circuit when illuminated.

Table 3-1. Controls and Indicators, Front (Continued)

REF.	CONTROL/INDICATOR	FUNCTION
45	PA SCRN OVERLOAD indicator (DS9)	Indicates excessive PA screen current has triggered the PA screen overload circuit when illuminated.
46	PA VSWR OVERLOAD indicator (DS8)	Indicates excessive antenna VSWR has triggered the PA VSWR overload circuit when illuminated.
47	IPA VSWR OVERLOAD indicator (DS7)	Indicates excessive PA grid circuit VSWR has triggered the IPA VSWR overload circuit when illuminated.
48	AFC OVERLOAD indicator (DS6)	Indicates the exciter AFC loop is unlocked when illuminated.
49	OVERLOAD IND RESET switch (S1)	Resets the overload indicators when depressed.
50	AIR INTERLOCK indicator (DS1)	Indicates the air interlock switch is open when illuminated.
51	FAULT INTERLOCK indicator (DS2)	When illuminated, indicates a fault has occurred repeatedly and activated the transmitter fault circuit.
52	XMTR CAB INTERLOCK indicator (DS3)	Indicates a transmitter rear door is open when illuminated.
53	HV CAB INTERLOCK indicator (DS4)	Indicates the high voltage cabinet front panel is open when illuminated.
54	EXT INTERLOCK indicator (DS5)	Indicates the external station interlock is open when illuminated.
55	+12V REG DC indicator (DS15)	Indicates an active output from the +12 Vdc regulator in the control circuit when illuminated.
56	-12V REG DC indicator (DS16)	Indicates an active output from the -12 Vdc regulator in the control circuit when illuminated.
57	LOCAL ONLY CONTROL indicator (DS12)	Indicates local control has been selected when illuminated.

Table 3-1. Controls and Indicators, Front (Continued)

REF.	CONTROL/INDICATOR	FUNCTION
58	LOCAL ONLY/NORM CONTROL switch (S3)	Selects between local or remote transmitter operation.
59	IPA VSWR overload set (R24)	Adjusts the overload trip point of IPA reflected power (FACTORY CALIBRATED).
60	PA VSWR overload set (R25)	Adjusts the overload trip point of PA reflected power (FACTORY CALIBRATED).
61	PA SCREEN overload set (R26)	Adjusts the overload trip point of PA screen current (FACTORY CALIBRATED).
62	PA plate overload set (R27)	Adjusts the overload trip point of PA plate current (FACTORY CALIBRATED).

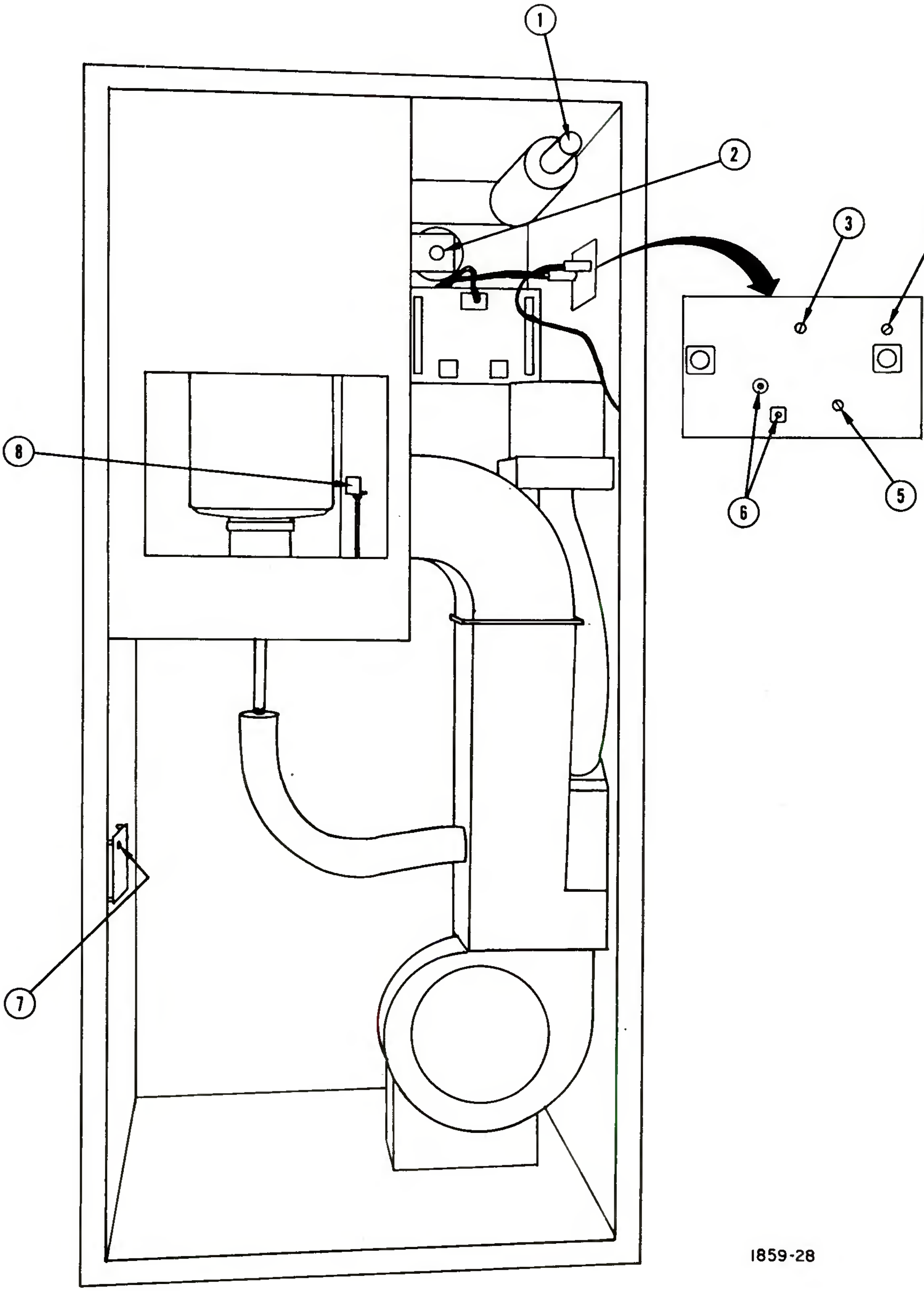


Figure 3-2. Controls and Indicators, Rear

Table 3-2. Controls and Indicators, Rear

REF.	CONTROL/INDICATOR	FUNCTION
1	SECOND HARMONIC NOTCH FILTER ADJUSTMENT (FL2)	Adjusts quarter wave stub to the second harmonic frequency of the PA.
2	AIR PRESSURE SWITCH ADJUSTMENT (S8)	Adjusts the air pressure switch drop-out point.
3	IPA MATCHING (C3)	Adjusts coupling of the IPA stage to the PA grid circuit.
4	IPA Tuning (C1)	Adjusts tuning of the IPA stage.
5	Second Harmonic Notch Adjustment (C2)	Tunes the IPA stage low-pass filter to the second harmonic frequency.
6	Directional Coupler Null Adjustments (C12, R2)	Adjusts IPA stage directional coupler for a null in reflected power.
7	Filament Meter Calibrate (R9)	Calibrates the MULTIMETER filament voltage display.
8	PA Neutralizing capacitor C_N	Adjusts PA stage neutralization at the fundamental frequency.

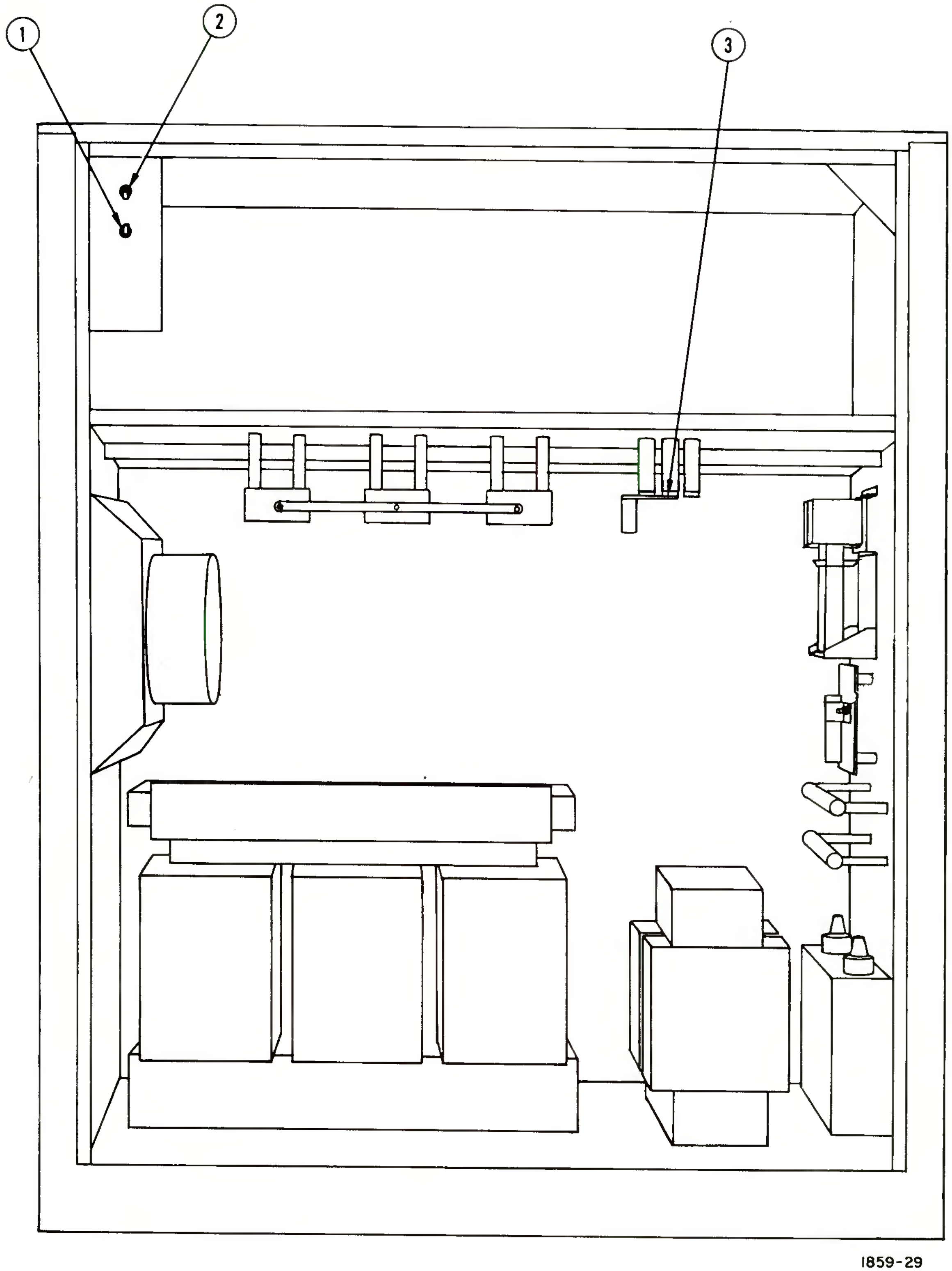


Figure 3-3. High Voltage Power Supply, Controls and Indicators

WARNING: Disconnect primary power prior to servicing.

Table 3-3. High Voltage Power Supply, Controls and Indicators

REF.	CONTROL/INDICATOR	FUNCTION
1	BLOWER circuit breaker (CB2)	Provides control and overload protection for the high voltage power supply flushing fan.
2	SCREEN circuit breaker (CB1)	Provides control and overload protection for the screen power supply. **WARNING** THE FULL PA PLATE VOLTAGE EXISTS ON THE ELEMENTS OF THE HIGH/LOW PLATE VOLTAGE SWITCH. NEVER ATTEMPT ADJUSTMENT OF SWITCH, S8, UNLESS ALL POWER IS DEENERGIZED AND THE SWITCH IS GROUNDED.
3	HIGH/LOW plate voltage switch (S8)	Allows a 50% reduction in the PA supply output voltage for tuning.

WARNING: Disconnect primary power prior to servicing.

Table 3-4. Power/VSWR Conversion

INDEX $\frac{\text{REF PWR}}{\text{FWD PWR}}$	RETURN LOSS	VSWR
0.00	∞ dB	1.0:1
.002	26.9 dB	1.1:1
.008	20.9 dB	1.2:1
.017	17.7 dB	1.3:1
.028	15.5 dB	1.4:1
.040	13.9 dB	1.5:1
.065	11.8 dB	1.75:1
.111	9.5	2.0:1
.183	7.3	2.5:1
.25	6.0	3.0:1
.36	4.4	4.0:1

VSWR may be calculated by:

$$\text{VSWR} = \frac{\left[1 + \sqrt{\frac{P_{REF}}{P_{FWD}}}\right]}{\left[1 - \sqrt{\frac{P_{REF}}{P_{FWD}}}\right]}$$

P_{REF} = POWER REFLECTED IN WATTS
P_{FWD} = POWER FORWARD IN WATTS

WARNING: Disconnect primary power prior to servicing.

SECTION IV

PRINCIPLES OF OPERATION

4-1. INTRODUCTION

4-2. This section presents detailed principles of operation with supporting diagrams.

4-3. FUNCTIONAL DESCRIPTION

4-4. POWER SUPPLIES

4-5. The following text describes the power supply circuitry of the FM-25K transmitter. Refer to figure 4-1 and the diagrams in Section VIII as necessary.

4-6. HIGH VOLTAGE POWER SUPPLY. The Harris FM-25K high voltage power supply produces the proper plate and screen voltages for operation of the FM-25K transmitter over its entire rated output power range. The primary of the supply is designed to operate from a 208/240 Vac, 50/60 Hz, 3Ø, three-wire source or a 360/415 Vac, 50/60 Hz, 3Ø, four-wire source. A fan in the power supply cabinet ensures cool and dependable operation. The BLOWER circuit breaker provides control and overload protection for the fan.

4-7. Primary Control Circuit. Assuming all FM-25K interlocks are closed, the high voltage supply primary circuit overloads are closed, and the PA filament heating delay has expired, a ground from the ac control module (1A12) in the control circuit will energize step/start relay K4. Power will be applied to the transformers in the high voltage power supply through resistors which limit the initial inrush of current. After a short mechanical delay, high voltage contactor K3 will close and bypass the step/start resistors to apply full line voltage to the plate and screen supplies. The step/start arrangement allows the supplies to gradually increase output which results in longer compoent life. If an interlock should open when the power supply is energized, both K3 and K4 will open and deenergize the primary circuit of T1. In addition, high voltage shorting switches L1 and L2 will discharge the plate supply to ground.

4-8. Plate Power Supply. The plate power supply primary is connected in a closed-delta configuration for 208/240 VRMS mains (see figure 4-2). A half-voltage supply is provided from the transformer center tap. Due to the physical construction of the transformer, each secondary phase will lead or lag its respective primary phase by 60 degrees in phase. The secondary phase separation (60°) divided into one cycle of primary phase rotation (360°) will equal six secondary phases. The six-phase circuit used in the FM-25K requires little filtering as 4% ripple is approached without using a filter (see table 4-1).

4-9. A requirement of all multiphase supplies is that the three-phase primary line voltage must be balanced to within the percentage of ripple voltage which is to be obtained from the power supply. The principle output

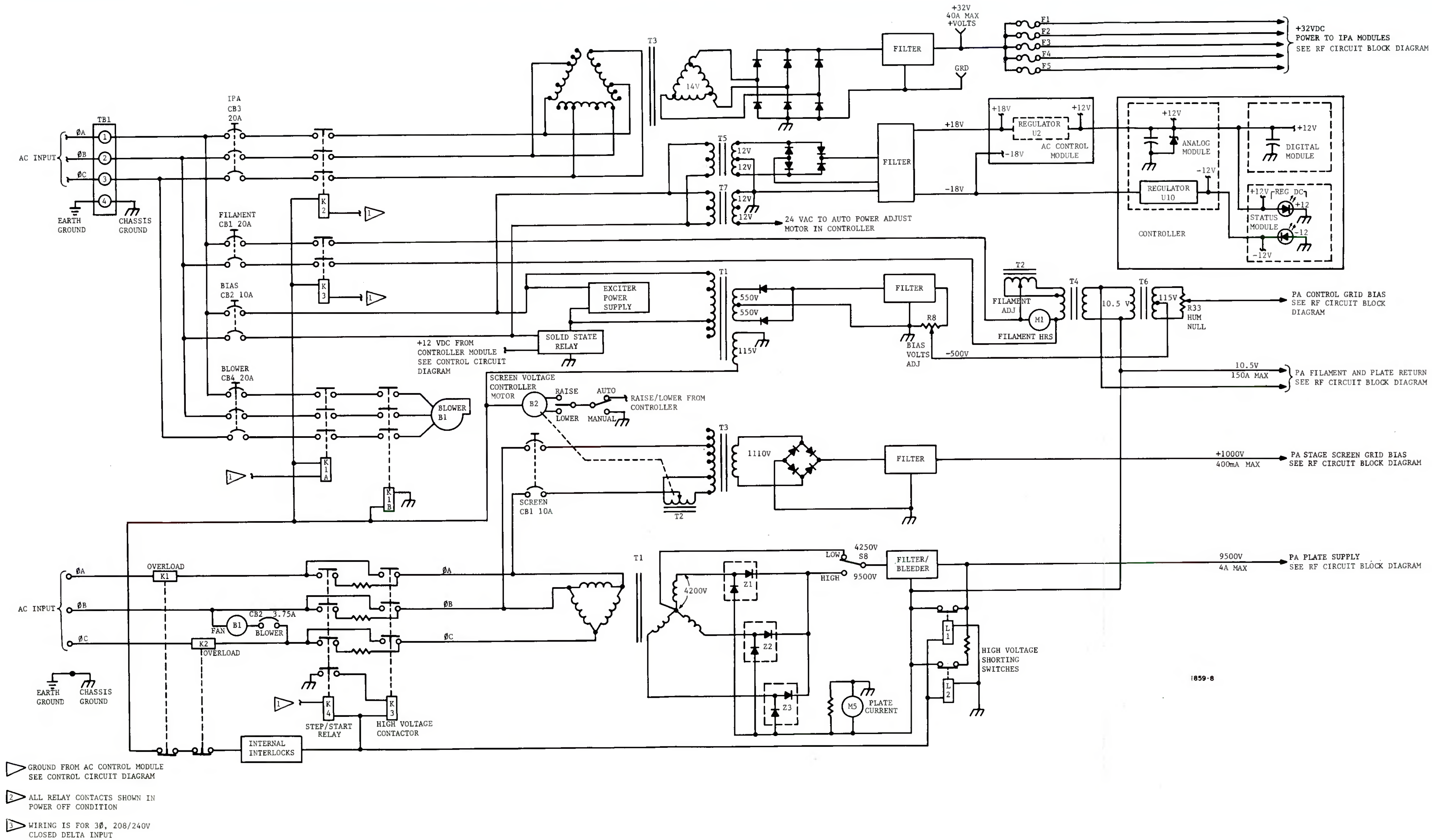


FIGURE 4-1. POWER DISTRIBUTION

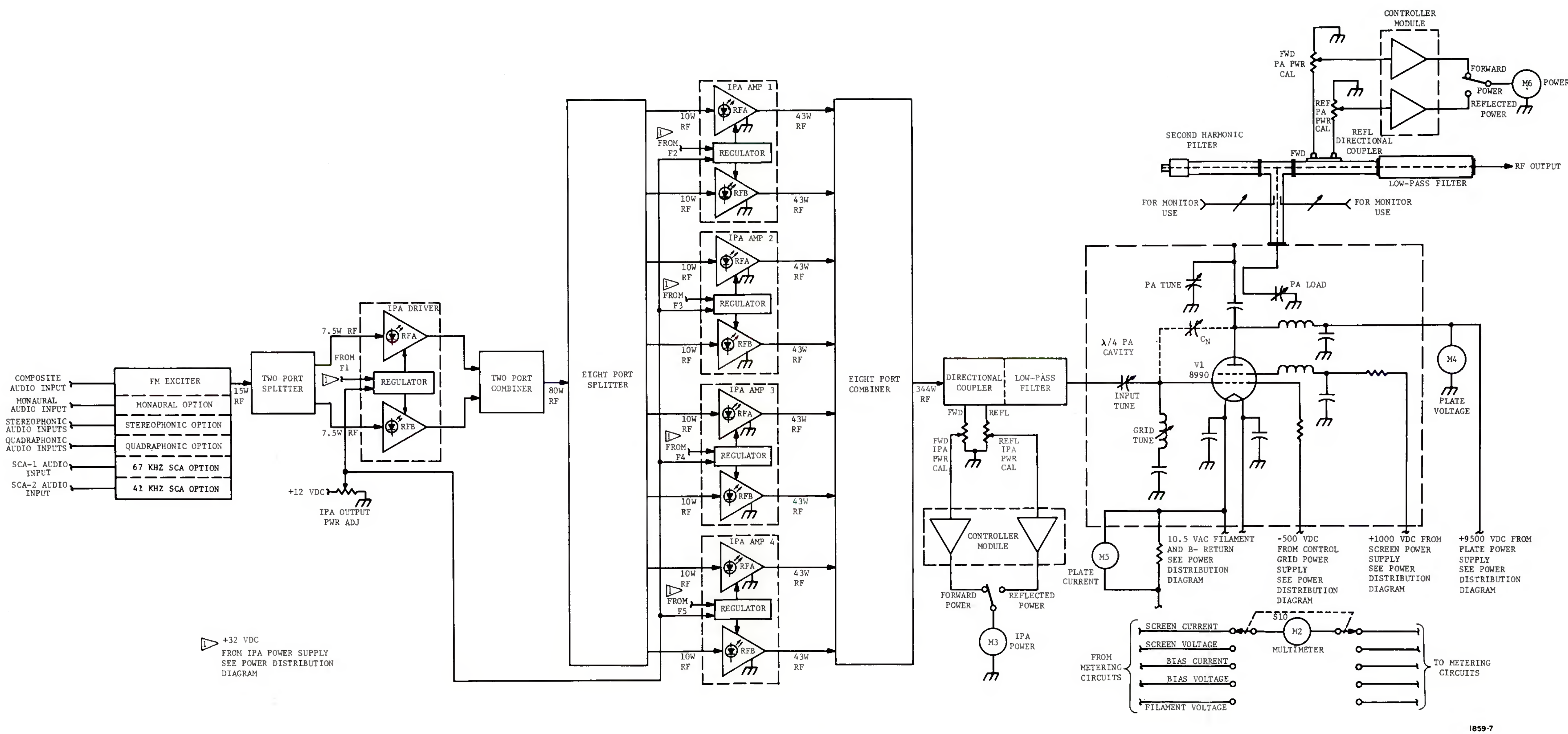
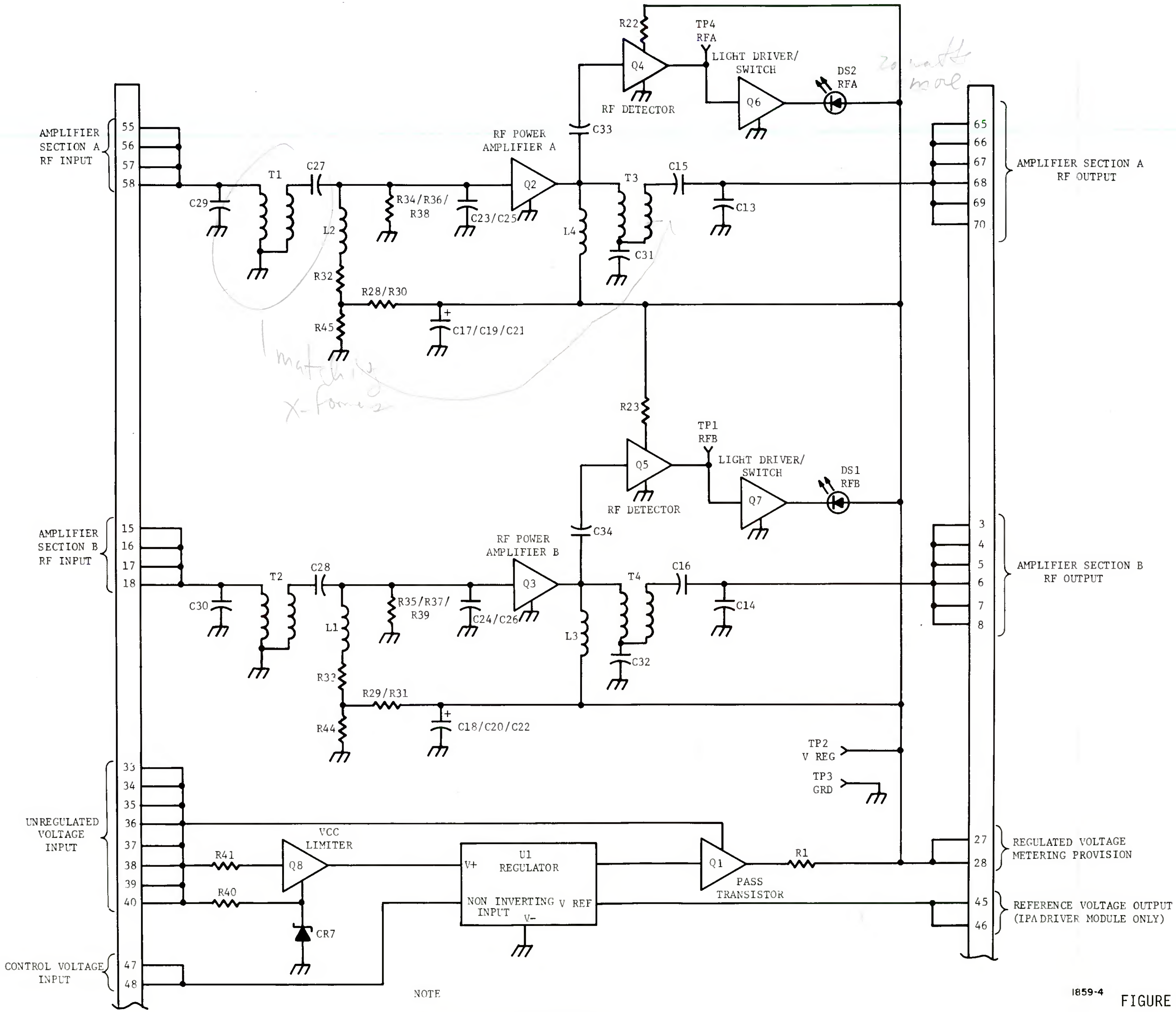


FIGURE 4-3. RF CIRCUIT BLOCK DIAGRAM



NOTE

PINS 1,2,9,10,11,12,19,20,21, 22,23,24,29,30,43,44,49, 50,51,52,53,54,61,62,63, 64,71, AND 72 CONNECT TO GROUND.

1859-4

FIGURE 4-5. SIMPLIFIED SCHEMATIC RF AMPLIFIER MODULE

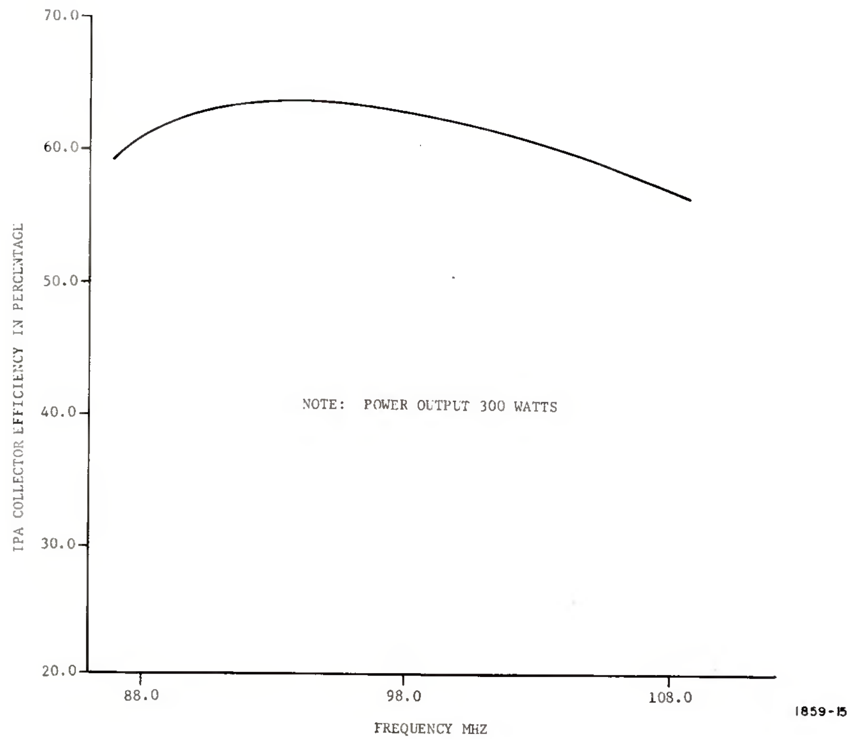


Figure 4-6. Typical IPA Stage Efficiency

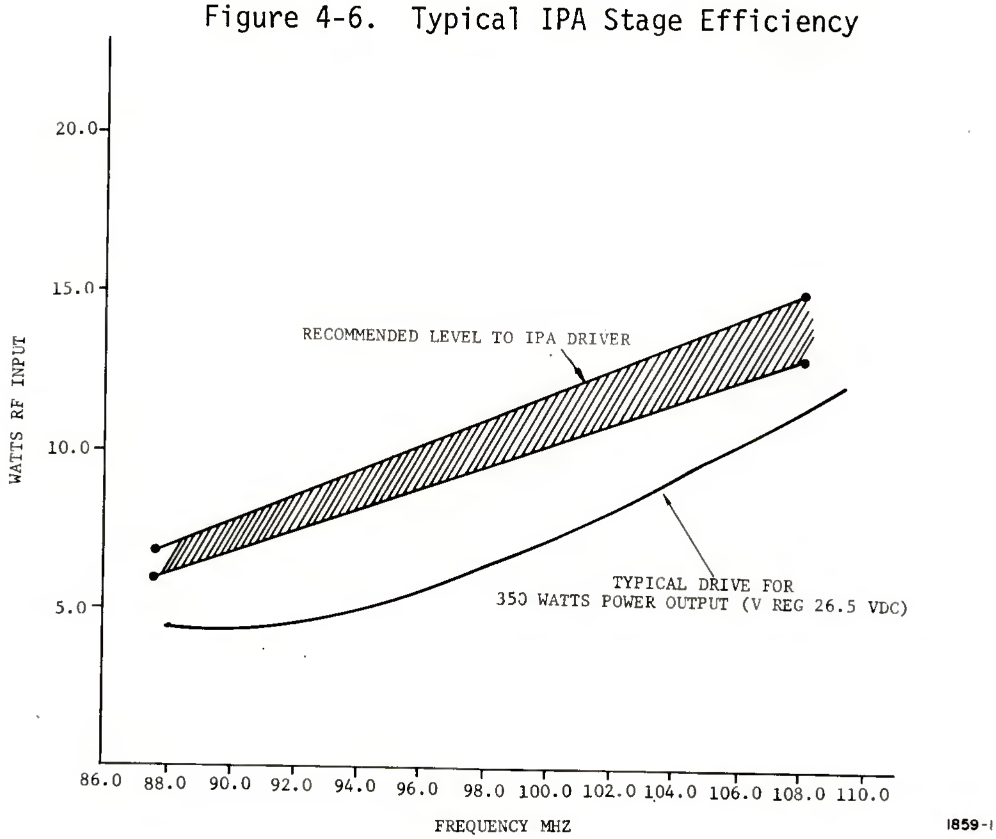


Figure 4-7. Exciter Driver Requirements

WARNING: Disconnect primary power prior to servicing.

4-41. The operation of the IPA AMP is further optimized by the length of coaxial cable between the two-port combiner and the eight-port splitter. The following graph provides information to obtain the best matching (see figure 4-8).

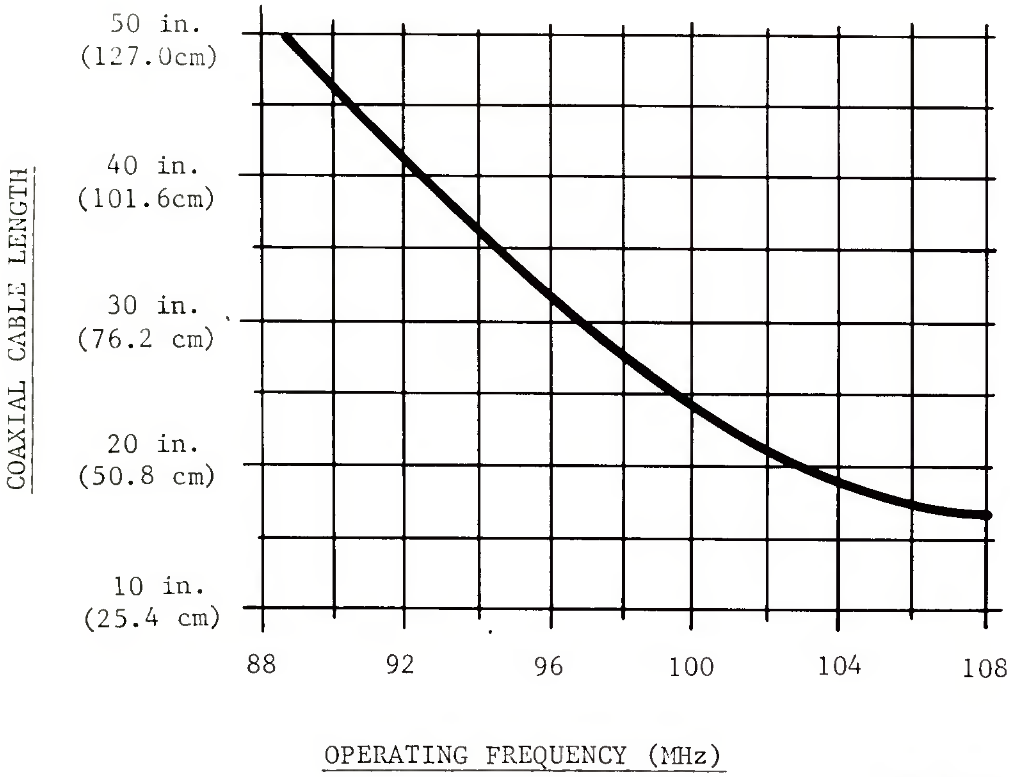


Figure 4-8. IPA Amplifier Stage Optimization

4-42. The amplifier is forward biased through resistors R28, R30, R45, and RF choke L2. Resistors R34, R36, and R38 help stabilize the bias level and provide a low impedance at the base junction of Q2 to prevent the generation of spurious outputs when the input signal reverse biases the amplifier base junction. Capacitors C17, C19, and C21 prevent any stray RF from affecting the operation of the adjacent amplifier section.

4-43. The collector of Q2 is supplied with an adjustable potential of +13 to +27 Vdc from the dc regulator through RF choke L4. Transformer T3 is a modified broadband hybrid transformer which utilizes a section of 25 ohm coaxial cable to match the five ohm output impedance of Q2 to the desired 50 ohm module output. Capacitors C13 and C31 resonate the transformer and C15 provides dc blocking.

4-44. A small portion of RF is coupled through C33 to RF detector Q4. The output of Q4 connects to the RFA test point (TP4). RF applied to the base of Q4 is rectified by the base-emitter junction and biases the transistor on in relation to the amount of RF signal present. The amount of current passed through the emitter junction may be measured from the module front panel to provide a representation of RF output power. Typically, the voltage present at the RFA test point will be 1.0 Vdc with 50 watts output from Q2. The potential must be measured by a meter with a 20k ohms/volt sensitivity or greater.

4-45. The potential output by Q4 is also applied to the base of light driver/switch Q6. When the potential exceeds a preset threshold (20 watts of RF), Q6 will turn on and illuminate the RFA indicator.

4-46. MODULE POWER SUPPLY. The unregulated voltage input (typically 5 to 8 volts above the nominal regulated voltage output) is supplied to two series pass transistors (Q8 and Q1). The first transistor (Q8) functions to limit the maximum voltage applied to regulator U1 to a maximum of 35 volts. The pass transistor (Q1) actually supplies the regulated current to the two RF devices. As the regultor circuit has current limiting protection as well as current foldback protection, if a short is placed on the power supply output stage, no damage will be incurred. Figures 4-9 and 4-10 provide data reflecting power supply requirement versus power output and frequency.

4-47. Regulator. Monolithic regulator U1 consists internally of four sections: the reference, the error amplifier, the shutdown circuitry, and the output circuit.

4-48. Regulator U1 contains an internal temperature compensated 7.15 volt nominal reference established by precision zener diodes which is available on module pins 45 and 46. This voltage is connected to the external IPA OUTPUT PWR ADJ control for the module in the IPA DRIVER position, but is not used in the case of the IPA AMP modules. The variable voltage supplied from the wiper of the IPA OUTPUT PWR ADJ control is then returned to the control inputs of regulator U1 on all modules (pins 47 and 48) which ensures the regulated voltage output of all modules will be identical. Resistor R3 protects the reference within U1 in the event of a short circuit on the module reference voltage output.

4-49. The error amplifier portion adjusts the output stage voltage to ensure that the regulated voltage for all RF amplifiers is constant, regardless of the input potential. Capacitor C3 provides a low pass response for the error amplifier to ensure adequate load and input transient response with good stability.

4-50. The current limiting portion of U1 is capable of shutting off Q1 if the current limit sense terminal (CS terminal) voltage increases to approximately 0.62 volts. This will turn the internal current limiting transistor on. This 0.62 volt potential is supplied in one of two ways, depending upon the type of improper regulator load to which the circuit is reacting. If the regulator output becomes directly shorted, the internal current limiting transistor will be held on by a combination of voltage drop across the parallel combination of resistors R1 and R2 (0.12 volts) and an additional drop established across R9 of approximately 0.5 volts. The diode string of CR1 through CR4 allows for temperature compensation and input voltage stabilization of the foldback and current limiting functions. The combination of resistors R1, R2, R5, and R9 establishes the current supplied under short cir-

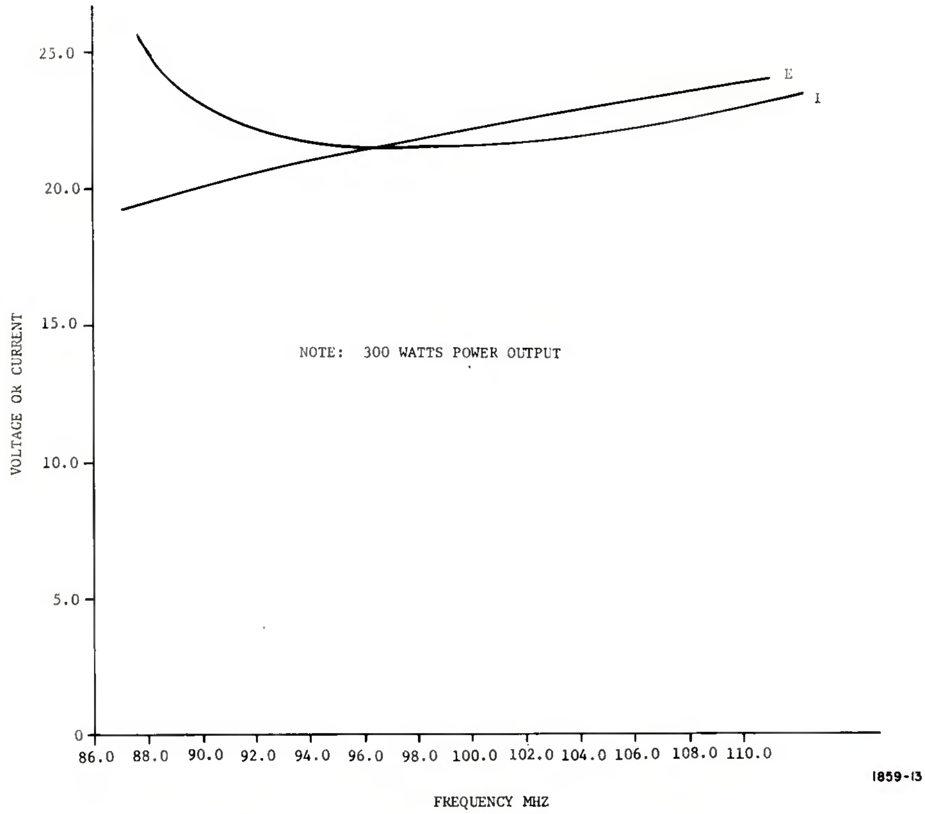


Figure 4-9. RF Power vs Regulated Voltage

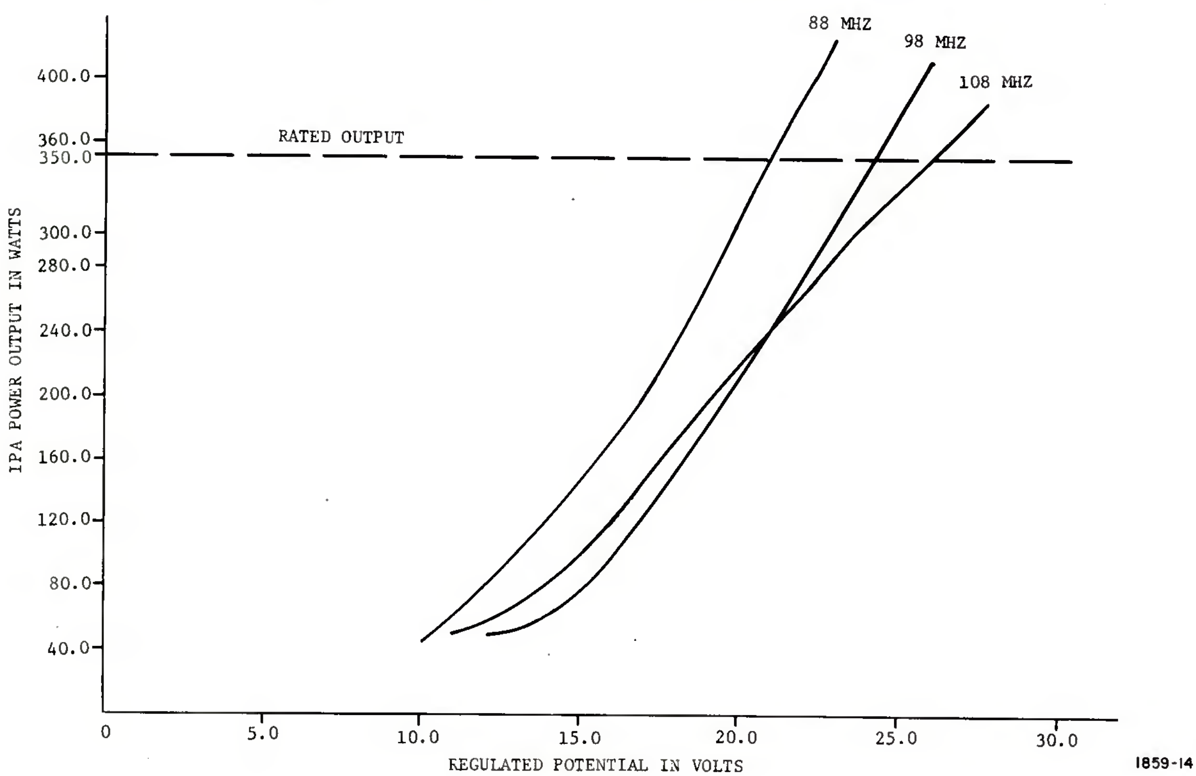


Figure 4-10. Typical IPA AMP Stage Power Requirements vs Frequency

WARNING: Disconnect primary power prior to servicing.

cuit conditions to approximately 2.5 amperes as well as the normal load current supplied under high amplifier drive conditions. Resistor R12 provides a current sink for the regulator under no load conditions to ensure that the quiescent currents in the shutdown section remain biased above zero volts.

4-51. A second type of regulation occurs when the load current is much higher than normal, but not enough to be termed a direct short. In this case, the regulator will supply the normal regulated voltage minus a small fraction of a volt, indicating that the current limit point has been exceeded. In this case, the current limit potential will be developed by the voltage drop acros the parallel combination of resistors R1 and R2 almost entirely. At a load current of approximately 12.4 amperes, the voltage dropped across R1 and R2 will increase to 0.62 volts and the regulator voltage will begin to decrease. The voltage drop across R1 and R2 is also available as an indication of module total current.

4-52. The possibility of an overload type between the two discussed overloads exists where the foldback load current will be somewhere between 2.5 amperes and 12.5 amperes. In this situation, the shutdown potential will be produced from a combination of the resistor drops discussed. If this type of overload occurs, the regulator output voltage will be between zero and the no load voltage.

4-53. Pass Transistor. The voltage regulator pass transistor is capable of supplying 13 to 27 volts at currents up to 10 amperes to the two RF amplifier devices. This stage will dissipate approximately 40 to 64 watts under normal operation. In the case of a short circuit on the regulator output, the device dissipation will increase to 72 to 80 watts. This device has been selected to operate in this condition for an indefinite period without damage.

4-54. Resistor R7 protects the output of U1 in event a short develops in the pass transistor. Capacitor C36 holds Q1 off until U1 is fully on, assuring a proper regulator initial turn-on sequence.

4-55. The regulated dc voltage output by Q1 on each individual module may be measured using an external meter at the V REG module test point with respect to the GRD test point (chassis ground).

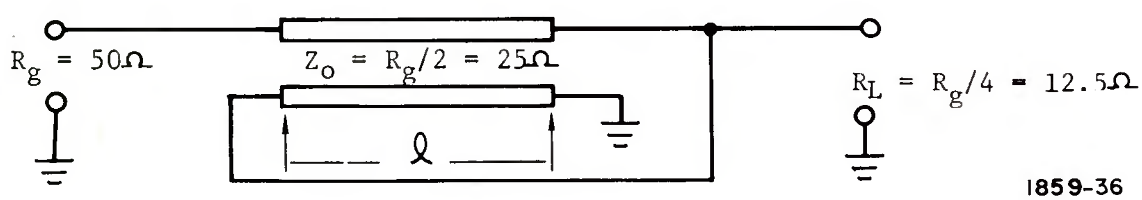
4-56. EIGHT PORT COMBINER. The eight port combiner performs the functions of combining the eight individual outputs of the RF amplifiers and providing a 50 ohm output load for each amplifier. The combiner inputs exhibits a constant impedance under all types of amplifier output conditions by virtue of the isolation existing between each of the eight input ports. This means that if the output of any amplifier exhibits a high VSWR (due to a transistor or other failure) the impedance seen by the remaining working amplifiers will remain 50 ohms. Under these conditions some of the power from each of the seven remaining amplifiers will be dissipated in the load resistors. This does not happen if all eight amplifiers are working, therefore the combining efficiency is very high, typically greater than 90%. In the event of the failure of one amplifier, the combining efficiency is 80% and two amplifiers fail, it is 68%. Isolation between amplifier ports is a minimum of 15 dB.

4-57. The insertion phase from any one of the 8 inputs to the output is constant, therefore the eight port combiner is termed a "zero degree" combiner. This type of combiner has an advantage in that the phase of the amplifiers are not pulled in opposite directions if an output mismatch occurs.

4-58. Modified Broadband Hybrid Matching Transformers. The modified hybrid transmission line transformer may be used as an impedance matching device over a relatively wide bandwidth. It uses few components and exhibits low loss matching characteristics. Any impedance ratio may be attained with this technique as it is not limited to ratios relating to the squares of integers such as 1:1, 4:1, 9:1, and 16:1. The use of these transformers helps facilitate design of "untuned" amplifiers. Another advantage of these transformers is that the impedance at the second harmonic seen by a transistor is much closer to the impedance at the fundamental frequency when compared to a Chebishev network with the same impedance matching ratio. This factor minimizes spurious frequency generation under mismatch conditions at high frequencies.

4-59. The transformation ratio of 8:1 provides a one-step impedance match from the low impedance RF amplifier output to 50 ohms. When the base impedance is resonated by a shunt capacitive element to appear resistive only, the 8:1 ratio will step the base impedance up to 50 ohms.

4-60. The 8:1 transformer operation can best be described by first examining the 4:1 transmission line transformer shown below:



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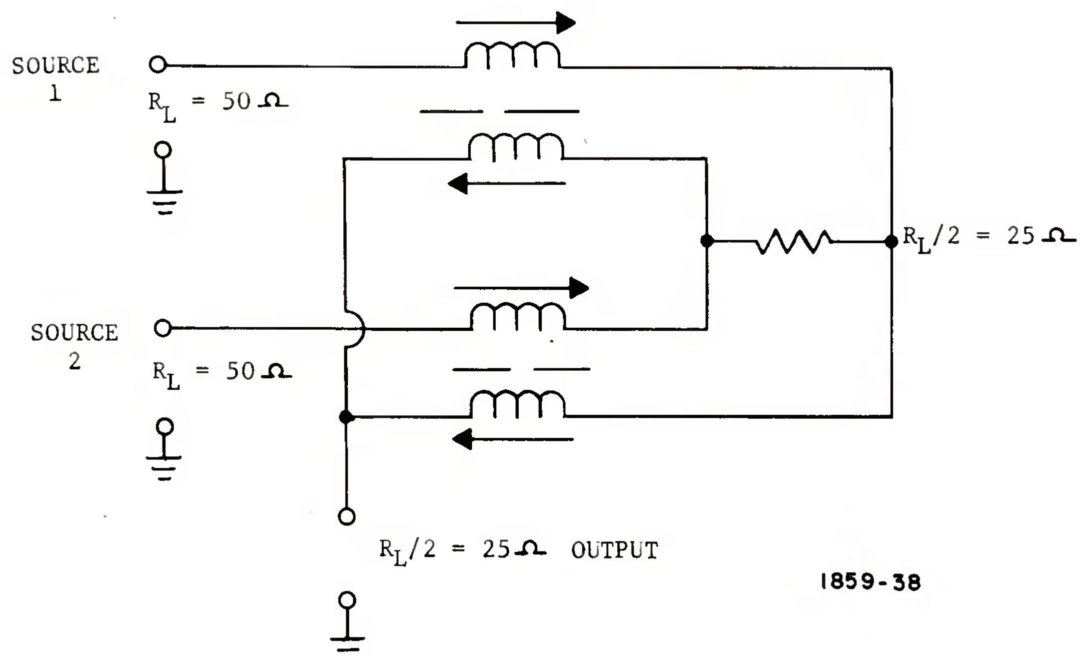
This transformer is capable of matching a single ended source to a single ended load and providing reactance-free operation over a broad frequency range. The high frequency cut-off is determined by the charactersitics of a length of 25 ohm coaxial line. If the line is too short, the low frequency performance will be limited.

4-61. The basic 4:1 transformer is modified in two ways. In order to provide a 8:1 impedance match, the coax cable impedance remains the same but the length is shortened slightly. Capacitors are then used to compensate the transformer at both high and low frequencies. One capacitor is placed in series with the low impedance side, and another capacitor is placed in shunt with the high impedance side. This 8:1 transformer is used for matching in the dual RF amplifier eight port splitter and eight port combiner.

4-62. In order to provide a 2:1 impedance match, 50 ohm coaxial cable must be used. A shunt capacitor is added from the low impedance side to ground, as well as a series capacitor on the low side. In addition a series inductance is added on the high impedance side. The two capacitors provide a capacitance tap from 25 ohms down to the lower input impedance of the transformer of approximately 20 ohms. This 2:1 transformer is used in the two port combiner. Additionally, all the transformers discussed exhibit a dc ground potential at the matching point.

4-63. FM-25K Combiner Circuits. The basic building block used in the FM-25K eight port combiner is the basic hybrid circuit illustrated below:



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4-64. If the two 50 ohm sources are equal in amplitude and phase, the theoretical combining efficiency will be 100%. Since these are sections of 50 ohm transmission line conductors the uniform distributed capacitance and compliments the series distributed inductance to provide reactance-free operation over a broad frequency range.

4-65. The basic eight port combiner circuit is constructed with eight coaxial cables (T1 through T8) results in a common point impedance where the coaxial cable shields connect together of 50 ÷ 8 = 6.25 ohms. A match from the 6.25 ohm point to the output impedance of approximately 50 ohms is provided by capacitor C9 and transformers T9 and T10. Capacitors C1 through C8 function to resonate the inductance exhibited by the eight input ports at the high end of the commercial FM broadcast band. Capacitors C11 through C18 cancels the inherent inductance of the 22 ohm combiner load resistors (R1 through R8).

WARNING: Disconnect primary power prior to servicing.

4-66. Adequate air cooling is provided for the eight port combiner load resistors where the power dissipated in any one resistor will be 37 watts maximum, in the worst case. No dc voltage is present in the combiner network and the combiner output is a dc ground potential which helps to provide isolation for the amplifier outputs. The position of the input jacks in a symmetrical circular arrangement assures uniform phase and amplitude relationships within the combiner circuitry.

4-67. LOW-PASS FILTER AND DIRECTIONAL COUPLER. The output circuit includes a low-pass filter and a directional coupler complete on one printed circuit board.

4-68. Low-Pass Filter. A PI section low-pass filter comprises C3 which functions as an IPA tuning control, inductors L2 and L4, and capacitor C3 which functions as an IPA loading control. Additional components function as a second harmonic notch filter. Capacitor C2 provides a second harmonic notch filter adjustment.

4-69. Directional Coupler. The output circuit includes a directional coupler produced in printed circuit form with microstrip techniques using the principle that adjacent sections of microstrip transmission line share common inductive and capacitive coupling. The directional coupler provides two dc signals, each obtained by rectifying a voltage sample obtained from the transmission line circuitry. Because of the difference in directivity of the two samples, one output will be proportional to the forward traveling wave and the other sample will be proportional to the reflected traveling wave.

4-70. Forward Port. The forward port of the directional coupler develops a rectified RF voltage through CR2 produced along the sensing line which is terminated by the resistance of R3. The resultant dc is filtered by C5, C6, C7, and L6 and applied to the forward power amplifier in the control circuit.

4-71. Reflected Port. The reflected port of the directional coupler is tuned across the entire commercial FM broadcast band by capacitors C8 and C9. Diode CR1 develops a rectified RF voltage produced along the sensing line which is terminated by the resistance of R1 and R2 and nulled by the combination of C12, L7, and R2. The resultant dc voltage is filtered by L5 and C10 and applied to the reflected power amplifier in the control circuitry.

4-72. PA STAGE

4-73. A single 8990 tetrode operated as a class C amplifier in a quarter-wave cavity functions as the FM-25K RF output stage. The quarter-wave cavity design ensures a wide bandwidth is maintained from the exciter VCO output to the transmitter RF output (see figure 4-11). Forced air cooling ensures cool PA stage operation and long PA tube life.

4-74. RF drive from the IPA stage is applied to the PA input circuit which is tuned for optimum matching by a coil-capacitor combination. The control grid bias is applied through a hum null control to the grid circuit which cancels filament emission hum from amplitude modulating the RF signal.

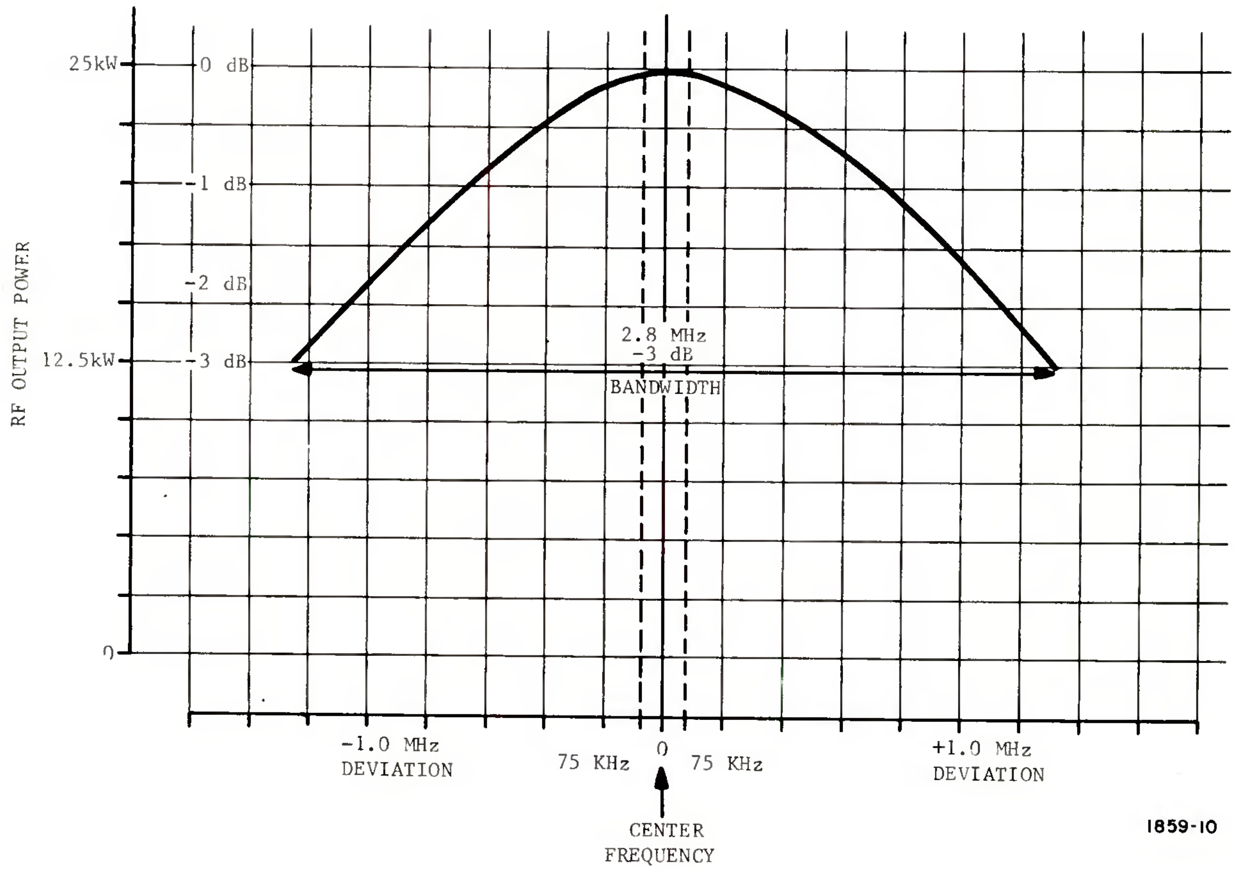


Figure 4-11. RF Bandwidth

4-75. The control grid blocking capacitor, the screen grid bypass capacitor, and the plate circuit blocking capacitor employ a thin film of Kapton material as insulation. This provides good isolation and stability at the close tolerances required in the PA cavity.

4-76. Output coupling is accomplished by capacity tuning and loading controls. A dc blocking capacitor ensures the PA tune control and the cavity both operate at dc ground potential. RF output is coupled to the antenna through a second harmonic filter, directional coupler, and a low-pass filter arrangement. RF coupling loops in the filter assembly provide a means to monitor the transmitter RF output.

4-77. DIRECTIONAL COUPLER

4-78. The directional coupler senses the RF output and provides two dc signals, each obtained by rectifying a voltage sample obtained from the transmission line. Because of the directivity of the two samples, one output will be proportional to the forward traveling wave and the other sample will be proportional to the reflected traveling wave. The two dc voltages are applied to amplifiers in the controller section for display by the metering circuit.

4-79. CONTROL CIRCUITS

4-80. The following text describes the control circuitry of the FM-25K transmitter. Refer to figure 4-12, Control Logic Functional Diagram and the applicable diagrams in Section VIII as required.

4-81. CONTROL LOGIC. The control logic for the FM-25K consists of three main boards. The digital board contains the actual control circuits, timers, and overload circuitry. The analog board provides an interfacing between the digital board, status board, and the actual transmitter. The status board contains the indicators and controls associated with the control logic. Figure 4-12 is a logic diagram containing a simplified schematic of the three main boards interfaced with the transmitter. Refer to figure 4-12 for the following discussion.

4-82. <u>Filament Turn On</u>. A filament on command from remote control equipment, from extended control equipment, or from the local FIL ON pushbutton is applied to an OR gate. The signal from the OR gate operates the filament latch relay, opening its contact, and operates the blower latch relay, closing its contact. The signal also resets the blower run-down timer, the blower flip-flop, and the thermal (loss of phase) overloads of blower contactor K1. When the blower latch contact is closed, solid state relay K4 is activated which applies voltage to the primary of transformer T1. One secondary of T1 provides stepped-up voltage to the bias supply. The second secondary functions as an isolation transformer providing 120 Vac to energize blower contactor K1. It also provides 120 Vac through interlock switches to energize the drop solenoid assembly. When the filament latch relay contacts open, one of the two inputs of the following filament gate is completed. When blower air has increased enough to close the air interlock, the second gate input goes HIGH and the entire filament gate input is satis-

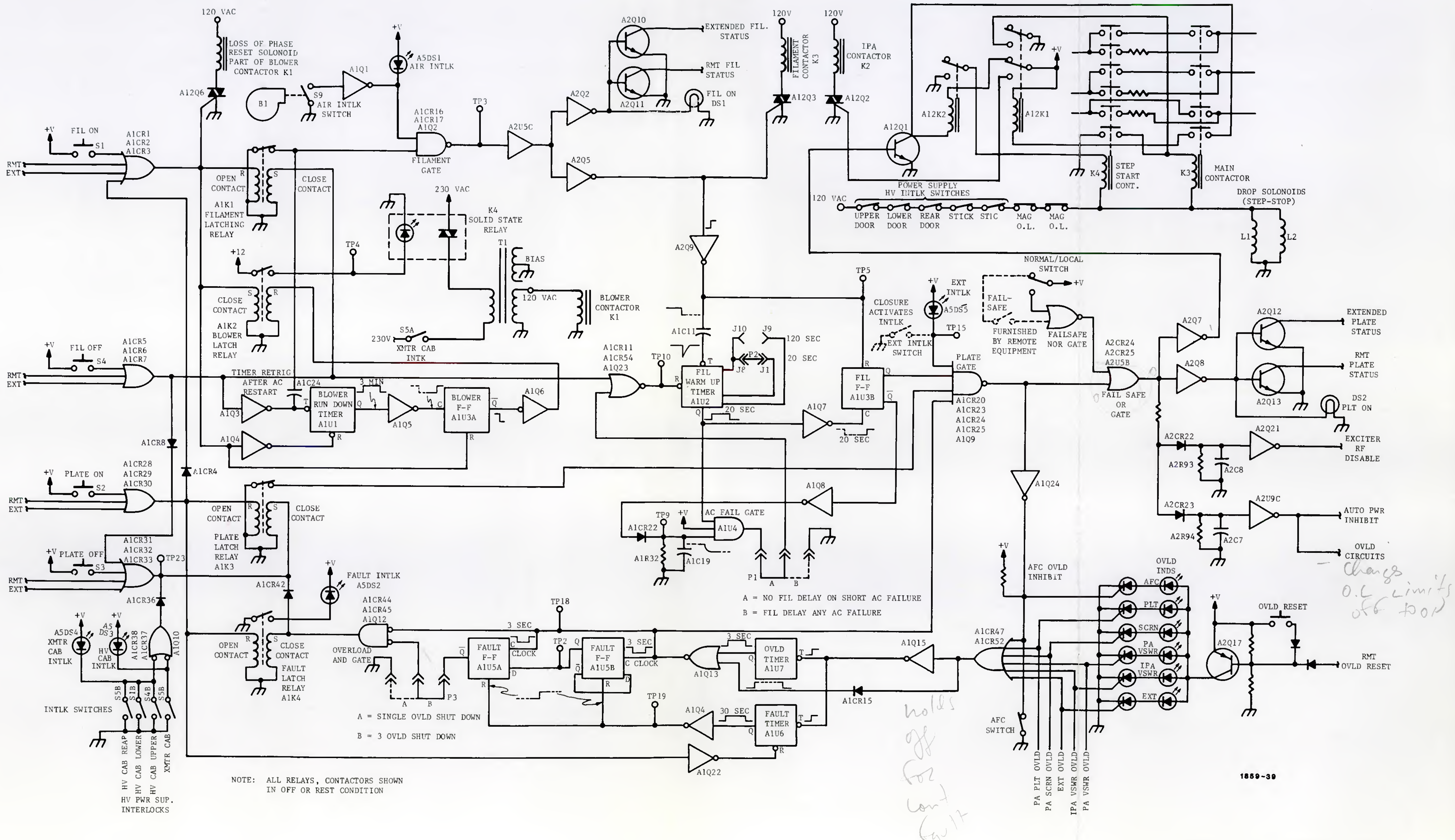


FIGURE 4-12. CONTROL LOGIC FUNCTIONAL DIAGRAM

fied. The filament gate is now activated and supplies a signal via a buffer and an inverter to the gate of a triac controlling the filament contactor. The filament contactor will energize by conducting through the triac to ground applying voltage to the filament transformer. If the control signal on the triac's gate is removed, the filament contactor will deenergize when the triac ceases conduction on the first zero-crossing of the 120 Vac applied to the contactor. The FILAMENT ON indicator, extended filament status circuit, and remote filament status circuit, also receive a positive control signal from the filament gate. The filament gate output supplies a triggering signal to the filament warm-up timer and a reset pulse to the filament flip-flop. Note that there is a plug with two possible positions associated with the filament warm-up timer. This plug, P2, is used to choose either a 20 second or a 3 minute filament warm-up time. At the end of the warm-up timer a positive going clock pulse is applied to the input of the filament flip-flop. This clock pulse sets the Q output of the flip-flop HIGH and $\overline{Q}$ flip-flop output LOW. The Q output completes one input of the plate gate.

4-83. Plate Control. Four inputs to the plate gate must be satisfied before the plate can be turned on. One of the three remaining inputs is the external interlock. A representation of an external interlock closure is shown on the diagram. This closure could be a load water interlock or any other interlock for which it is desired that the plate return to ON condition as soon as the interlock is released without further commands. The transmitter is equipped with an indicator (LED) as shown to indicate the occurence of an external interlock. The third input to the plate gate comes from the overload circuit. Under normal conditions without any overloads present the output from the overload circuit is HIGH. Thus, three of the four inputs to the plate gate are now HIGH. The fourth input to the plate gate comes directly from the plate latching relay A1K3. This relay is activated by the local PLATE ON pushbutton or any plate on remote commands, and is OR gated directly to the plate latching relay. This command opens the plate latching relay contacts supplying the fourth HIGH input to allow completion of the plate gate. The output of the plate on input OR gate is also connected to an input of the filament on input OR gate. All of the preceding operations can be initiated by entering a PLATE ON command. As shown in the logic diagram, the PLATE ON command from the plate on OR gate is applied through diode A1CR4 to the filament on OR gate. In this manner, a PLATE ON command will initiate the entire turn on sequence of the transmitter as described in paragraphs 4-82 and 4-83. This is refered to as a one button start.

4-84. The LOW output of the plate gate is inverted and used to enable the AFC overload input to permit an exciter out-of-lock condition to remove the transmitter from the air once the transmitter is in operation. The LOW is also applied to one input of the failsafe OR gate. As long as one of the two inputs to the failsafe OR gate is HIGH the output will be HIGH preventing the plate voltage from being energized. The second input to the failsafe OR gate comes from a NOR gate whose output is HIGH until one of its two inputs is presented with a HIGH. When the front panel NORMAL/LOCAL switch is in the LOCAL position a HIGH is applied to one input of the failsafe NOR gate causing its output to go LOW enabling the failsafe OR gate. If the

NORMAL/LOCAL switch is in the NORMAL position +12 volts is furnished to the remote equipment, which provides a contact closure returning the +12 volts to the failsafe NOR gate as a HIGH. In the event that the remote equipment fails the closure opens presenting a low to the NOR gate disabling the failsafe OR gate and removing the transmitter plate voltage. The LOW output from the failsafe OR gate is inverted to illuminate the PLATE ON indicator and to drive the remote indicator circuits. A second inverter applies the plate on signal to the base of A12Q1 biasing it into conduction energizing relay A12K2 through normally closed contacts of A12K1. The closure of a set of contacts on the relay A12K2 in turn energizes the step-start contactor in the power supply applying voltage to the plate transformer primary through surge resistors. A set of contacts on the step-start contactor energizes the main contactor which bypasses the current limit resistors and applies full voltage to the primary. An additional set of contacts on the main contactor connect relay A12K1 to the collector of A12Q1. Since A12Q1 is biased into conduction by the plate on signal, relay A12K1 will energize applying +V to the triac controlling the IPA contactor and at the same time removing +V from relay A12K2. Another set of contacts on A12K1 supplies the 120 Vac return to the main contactor keeping it energized when the step-start contactor opens due to the removal of its 120 Vac return by A12K2.

4-85. Delayed plate on signals are provided by capacitor A2C8 discharging through A2R93 to the exciter RF disable circuit and by capacitor A2C7 discharging through A2R94 to the automatic power enable circuit. These delayed signals allow the plate voltage to reach full potential and stabilize prior to application of RF drive and automatic power control.

4-86. Plate turn off is accomplished either from the local PLATE OFF pushbutton or remote plate off commands. The plate off commands are OR gated and applied directly to the contact close coil of the plate latching relay. The closed contact applies a LOW to one of the plate gate inputs turning transistor A12Q1 off removing plate voltage.

4-87. Overload Circuits. When an overload occurs, an SCR associated with that overload input signal is triggered resulting in illumination of an LED on the front panel of the transmitter. That same overload input is applied to an OR gate input, the output of which triggers an overload timer and a fault timer. The overload timer produces a three second pulse which is inverted and becomes a LOW plate gate input signal. This pulse shuts off the plates for approximately 3 seconds. This same inverted signal is applied to two fault flip-flops and the overload AND gate. The end of the negative pulse becomes a positive going clock pulse causing the first flip-flop to change state such that the Q output becomes HIGH. The second flip-flop does not change state from this initial pulse because its data input line has been LOW. However, the first flip-flop Q output has now changed the second flip-flop data input line to a HIGH. If a second overload occurs, the overload signal is again applied to the OR gate and triggers the overload timer. The timer produces a three second pulse which is inverted. This pulse shuts off the plate for three seconds and clocks the second flip-flop causing the Q output to go HIGH. If a third overload occurs, it also is applied to the OR gate and triggers the overload timer.

This time, however, the overload timer output pulse after being inverted, along with the $\overline{Q}$ output of the second flip-flop completes the overload AND gate. The output of the overload AND gate becomes a plate off command applied to the plate off OR gate. The plate off OR gate output opens the plate latch relay contacts and turns off the transmitter plate voltage. The transmitter will not return to the plate on condition until a plate on command occurs. The output of the overload AND gate also operates a fault latch relay which illuminates the FAULT indicator. The operator then has an indication that three overloads have turned off the transmitter. Note that the plate on command resets the fault latch relay.

4-88. As mentioned previously, the fault timer is triggered from the initial overload. It produces a pulse of approximately 30 seconds. If two additional overloads have not occured within this 30 second period, the end of the 30 second pulse produces reset pulses for both fault flip-flops. The result of this action is that three overloads must occur within 30 seconds to set the transmitter to a condition where reapplication of the plate voltage requires an operator plate on command. Note that a plate on command will terminate the 30 second pulse by resetting the timer. Jumper plug P3 after the second flip-flop allows the transmitter to be operated in a mode such that any single overload will require an operator on command to re-establish plate voltage.

4-89. As has been described, the devices that illuminate the overload LED's are SCR's (silicon controlled rectifiers). Since an SCR will allow current flow after its trigger is removed, the SCR acts as a memory device maintaining the overload LED illumination even after the overload trigger signal has been removed. The overload LED's are extinguished by applying a positive voltage to the base of A2A17 biasing it off removing conduction through the LED's and SCR's.

4-90. Interlocks. As is shown in the logic diagram, interlock circuitry is connected to the plate off input OR gate to shut off transmitter plate voltage when the interlock occurs. The interlock switch provides a low to illuminate the appropriate LED indicator. When these interlocks are released, an operator plate on command must be given to re-establish plate voltage. When an external interlock is activated and released, an operator plate on command is not required because the external interlock is applied directly to the plate AND gate.

4-91. The FM-25K is also provided with a set of 120 Vac interlocks that consist of the other half of the controller interlock switches. The 120 Vac interlock switches are connected in a series loop providing 120 Vac to the drop solenoids, L1 and L2, in the high voltage power supply cabinet. When an interlock in the transmitter cabinet or power supply is opened two events occur simultaneously. One event that occurs is that one half of the interlock switch sends a plate off command to the controller which illuminates the proper interlock indicator and deenergizes the plate circuits. The other event that occurs is the other half of the interlock switch removes 120 Vac from the drop solenoids which deenergize and short the plate voltage line to ground through 100 ohms.

4-92. Filament Turn Off. Filament off is accomplished by applying a filament off command to the filament off input OR gate either via the transmitter front panel control or the remote filament off controls. The output of the filament off OR gate commands the filament latching relay to the contact close position, applies a plate off command through the plate OR gate, resets the filament warm-up timer, and initiates the blower run down timer. After the filaments and plates of the transmitter have been turned off the blower run down timer allows the blower to cool down the power tube for approximately 3 minutes before shutting off the blower. The signal from the filament off OR gate triggers the timer, the output of which is a 3 minute width pulse applied to an inverter. The end of the pulse produces a clock signal which triggers the blower flip-flop. Its Q output then goes LOW. This signal is inverted, resets the blower latch relay, and removes the voltage from the solid state blower relay and the blower contactor, shutting off the blower.

4-93. The filament off signal from the filament off OR gate also resets the filament warm-up timer. Thus assures the filament warm-up timer is prepared to accept the next filament on trigger signal.

4-94. AC Failure Circuits. The filament, blower, plate, and fault circuits are equipped with latching relays which inherently have memory capability independent of ac power failures. After an ac power failure these devices will remain in the state they were in before the failure. Another device associated with ac power failure is the ac fail gate. This device with its associated capacitor and resistor times the ac power failure and modifies the filament warm-up time accordingly when power returns. During normal operation the capacitor shown on the input of the ac fail gate is charged via the Q output from the filament flip-flop. During an ac power failure the capacitor discharges through the resistor A1R32. If the power failure has been brief the capacitor will not fully discharge. When power returns, the charge on the capacitor presents a HIGH to the input of the ac fail gate and the filament warm-up timer will begin timing again producing a HIGH which is applied to the second input of the ac fail gate. Also, when power has been applied V+ is now present at the third input of the ac fail gate. Under these conditions the output of the ac fail gate will be HIGH and applied to the input of the OR gate associated with the reset input on the filament warm-up timer. The output of the OR gate generates a reset command which will immediately terminate the timing pulse at the output of the timer. This action will trigger the filament flip-flop and turn the transmitter back on. The preceding events will occur after an ac power failure up to 10 seconds. After 10 seconds, the capacitor on the input of the ac fail gate will have been very nearly discharged. Therefore, when ac power is reapplied the input to the ac fail gate from the capacitor is LOW. The ac fail gate output will then be LOW and the reset command into the filament warm-up timer will not occur. The filament warm-up timer will complete its full timeout before plate voltage is reapplied. Jumper P1 on the output of the ac fail gate allows the operator to force a full warm-up period after any ac power failure. This may be desired in some installations; especially where tube life is of prime concern.

4-95. The last device associated with ac power failure is a capacitor on the trigger input of the blower run down timer. During the blower run down cycle, the filament latch relay contacts are closed discharging this capacitor. The purpose of this capacitor is to reset the blower run down timer in the event of an ac power failure during the blower run down cycle. If an ac power failure occurs, the discharged capacitor causes a LOW trigger input signal to the blower run down timer when power is restored. This will re- start the full blower run down timing cycle to ensure proper cool down.

4-96. Automatic Power Control. The FM-25K control logic contains circuitry used to maintain the transmitter output power within approximately two or four percent (selected) of the operator set power level. Refer to figure 4-13, Simplified Schematic Automatic Power Control for the following discussion.

4-97. Power out of the transmitter can be controlled by raising or lowering the screen voltage. Motor driven variable transformer, T2, connected to the primary of screen transformer, T3, will vary the dc screen voltage from approximately 740 volts to 1000 volts when operating at the 25 kW power level. This in turn will vary the transmitter power from approximately eight percent above 25 kW to fifteen percent below 25 kW. A front panel switch, S1, allows manual or automatic control of the motor B2. When the switch, S1, is in the MANUAL position, the POWER out RAISE/LOWER switch S2 provides the return line to operate the motor. In the AUTO position the return line for the motor is provided by triacs. With the MANUAL/AUTO switch in either position limit switches remove the return line if the transformer, T2, reaches the end of its range.

4-98. As previously stated, in the AUTO position of the MANUAL/AUTO switch the return line for the motor is provided by triacs. The control signals for the triacs are generated by the over power and under power comparators. As shown in the simplified schematic the reference voltage for both comparators is derived from the power set potentiometer R1, which acts as a variable voltage divider. The reference voltage is directly applied to the non-inverted input of the under power comparator. Reference voltage for the over power comparator is applied through an operational amplifier used as a non-inverting summing amplifier. The voltage from the power set potentiometer is added to a voltage derived from a fixed voltage divider consisting of resistors R52, R53, R5D, and R5E. Jumper plug P1 allows selection of one of two fixed voltages to be added. In this manner the reference voltage applied to the inverted input of the over power comparator is slightly higher than the reference voltage applied to the under power comparator. This difference in reference voltages sets the "window" of the automatic power control range. Changing the jumper increases or decreases the width of the "window" by increasing or decreasing the voltage added to the reference voltage of the over power comparator.

4-99. Transmitter forward power metering voltage is sampled and applied through a buffer to the non-inverted input of the over power comparator and the inverted input of the under power comparator. If the transmitter power out decreases causing the forward metering sample voltage to decrease below the reference voltage "window", the under power comparator output will go HIGH and be applied to the enable gate. Assuming the delayed plate on command is present and HIGH, the enable gate will output a HIGH to the power raise gate. The second input to the power raise gate will also be HIGH from the inverted output of the power lower gate. With both inputs satisfied, the power raise gate HIGH output is inverted twice and applied to the gate of the triac controlling the power raise return line of B2. When the transmitter power increases, the metering sample voltage will return to within the "window". As this happens the under power comparator output will return to LOW reversing the above sequence and removing the control signal from the triac gate. On the other extreme if the transmitter output power increases causing the metering sample voltage to increase above the "window", the over power comparator output will go HIGH and be applied to the enable gate. The output of the enable gate is gated through the power lower gate, inverted twice, and applied to the triac gate controlling the power lower return of B2. The outputs of the power raise and power lower gates are also connected to LED's to indicate the presence of a control signal.

4-100. A small amount of positive feedback or hysteresis is added to both comparators to ensure positive switching and prevent the risk of hunting. The feedback of the over power comparator (U7B) is to the forward power metering voltage input. When the forward power metering voltage (output of U7A) is less positive than the reference input voltage, the output of the comparator is low or ground. In this case, R55 and R56 form a voltage divider to ground so that the actual input to the comparator is 1% less than the output of buffer U7A. As the forward power metering voltage increases, it must go 1% above the reference voltage before the comparator will switch and its output goes high. Once it does switch the resistive divider (R55 and R56) is no longer referenced to ground, but to the positive output voltage. This causes the actual voltage at the forward metering input to be $\simeq$ 1% higher than the output of buffer U7A. As the auto power control system lowers the transmitter output power and the metering voltage decreases, it must go 1% below the reference before the comparator will switch to a low output. Once it does the voltage divider is again referenced to ground. The under power comparator (U7C) operates in the same manner except the 1% hysteresis, rather than modifying the forward power metering voltage, acts upon the reference voltage through the resistive divider formed by resistors R5H and R57.

4-101. The PWR SET potentiometer, which controls the reference voltage for the comparators, is a motorized potentiometer. Remote commands, extended commands, and local commands from the LOCAL PWR SET RAISE/LOWER switch are OR gated, inverted, and applied to the triacs controlling the motorized PWR SET potentiometer.

4-102. METERING

4-103. The following text describes the metering circuitry used to monitor the various operating parameters of the FM-25K transmitter.

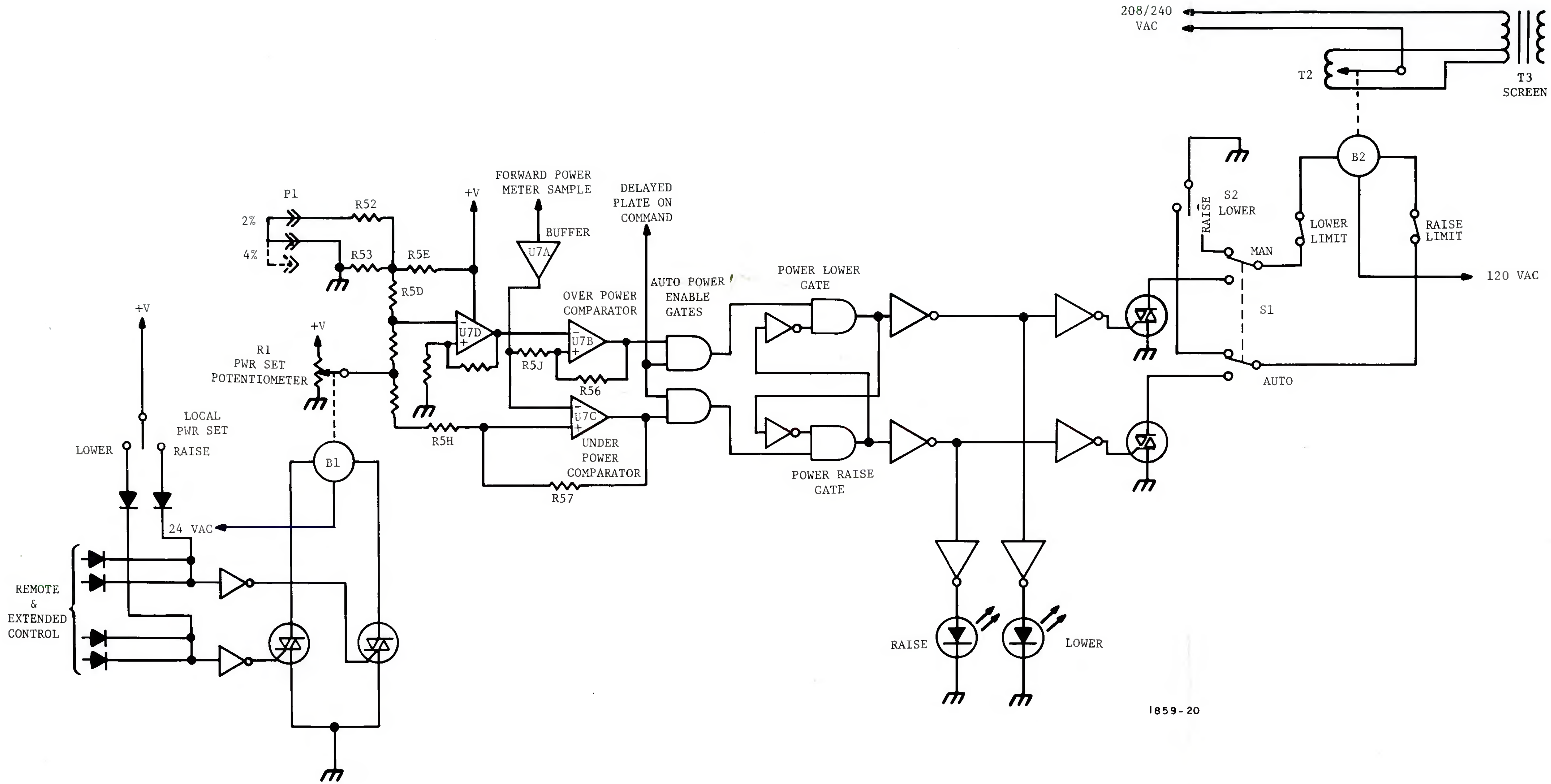


FIGURE 4-13. SIMPLIFIED SCHEMATIC
AUTOMATIC POWER CONTROL

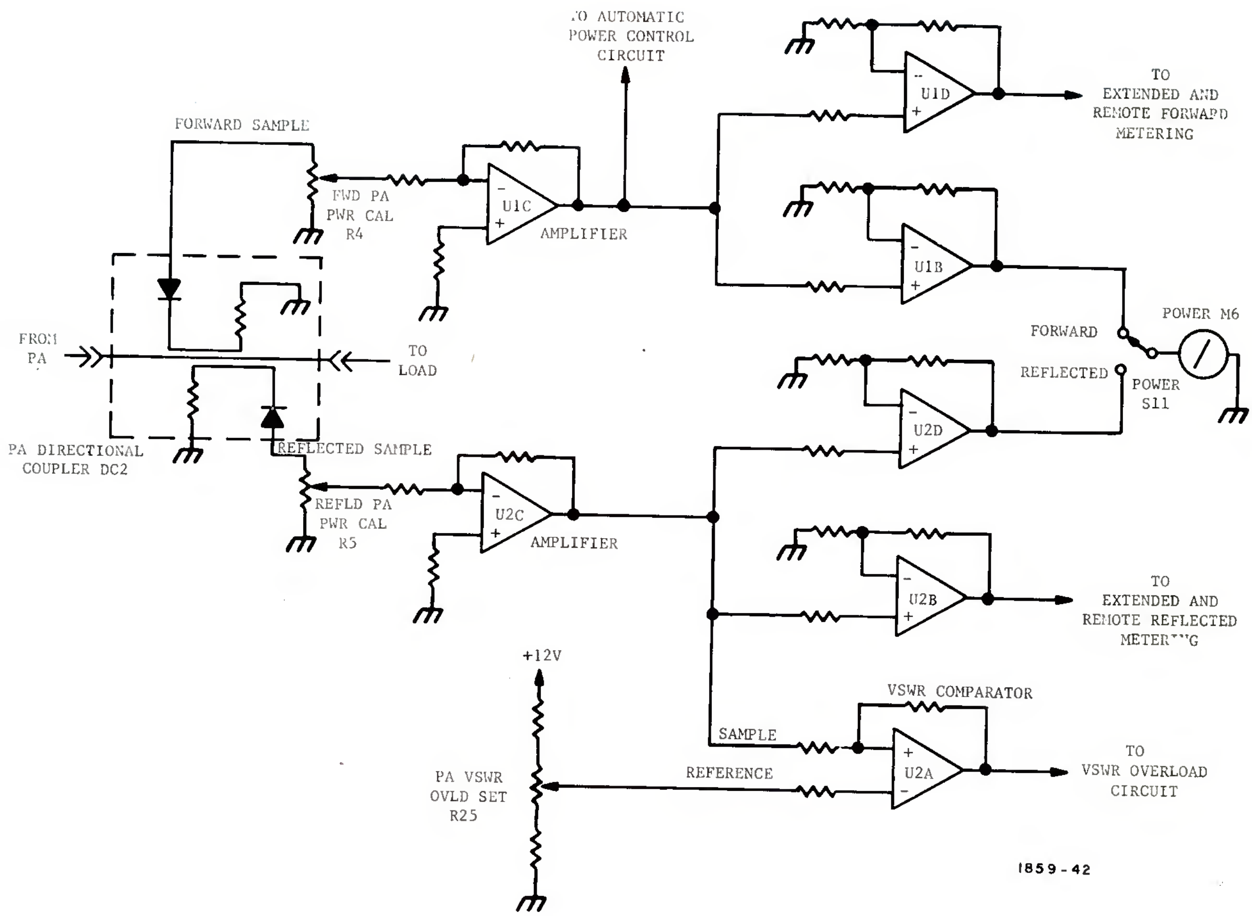


Figure 4-14. Simplified Power Metering

4-104. POWER METERING AND VSWR OVERLOADS. The analog circuit board of the control logic contains forward and reflected metering circuits for the power amplifier and the intermediate power amplifier. Since the circuits operate in an identical manner only the power amplifier circuits will be discussed. Refer to figure 4-14 for following discussion.

4-105. Figure 4-14, Simplified Power Metering, shows the relationship of the directional coupler, the meter, and the associated circuitry. The negative voltage from the directional coupler forward sample is applied through the forward calibration potentiometer to the inverting input of an amplifier. The output of this amplifier is again amplified without inversion and applied through the FORWARD/REFLECTED POWER switch to the positive terminal of the POWER meter. The negative terminal of the POWER meter is at ground potential. Remote and extended metering is provided by amplifying the output of the inverting amplifier. The reflected power is monitored in a similiar manner. An additional output of the reflected inverting amplifier is applied to the non-inverted input of a VSWR comparator. PA VSWR OVLD SET potentiometer, R25, acts as a voltage divider and supplies the reference voltage to the VSWR comparator. When the meter voltage exceeds the preset reference voltage the comparator output goes HIGH. This HIGH is applied to the overload circuitry discussed in paragraph 4-87. The forward metering voltage of the power amplifier is applied to the automatic power control circuitry described in paragraph 4-96.

4-106. PLATE METERING AND CURRENT OVERLOADS. Refer to figure 4-15, Simplified Metering, for the following discussion. Plate voltage and current are monitored by meters M4 and M5 respectfully. Resistors R20 and R21 (transmitter cabinet) are meter multipliers for the plate voltage meter. Resistors R11 through R15 (transmitter cabinet) act as parallel meter shunts for the plate current meter which is in the negative lead of the plate power supply. Resistors R17 through R19 (transmitter cabinet) are used as meter multipliers. The resistor R19 is selected for proper meter indication in factory test as the value may vary from transmitter to transmitter. Zener diode CR7 provides protection to the plate current meter. Resistors R12 through R16 (located in the power supply cabinet) provide the top leg of a voltage divider used for extended and remote plate voltage metering. A power amplifier plate current sample is provided through R16 (located in the transmitter cabinet) to the control logic overload circuits.

4-107. Refer to figure 4-16, Simplified Plate Current Overloads. The plate overload circuit consists of a fixed comparator and a variable comparator OR gated to the plate current overload SCR. When plate voltage is initially applied, the plate current sample is applied to the negative input of the fixed comparator. The positive input is from a voltage divider consisting of A2R41 and A2R42. If initial plate current exceeds nine amperes (determined by R41 and R42) the comparator output goes HIGH and is applied through the OR gate to the appropriate SCR. The plate current sample is also applied to the negative input to the variable comparator. The positive input to the variable comparator is derived from the voltage divider containing the PA PLT OVLD SET potentiometer, which is normally set for an overload of four amperes at 25 kW output. If the transmitter plate current

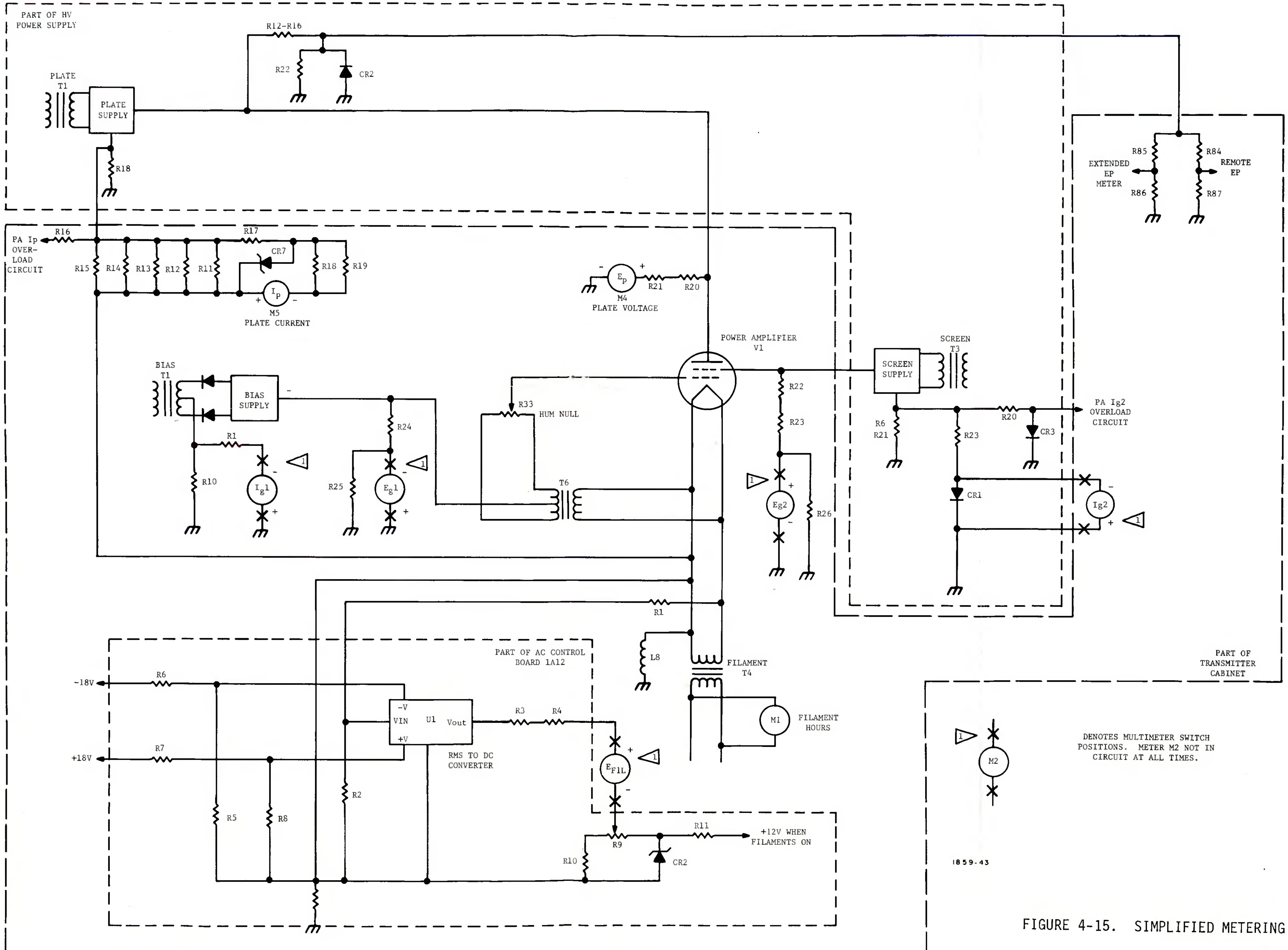


FIGURE 4-15. SIMPLIFIED METERING

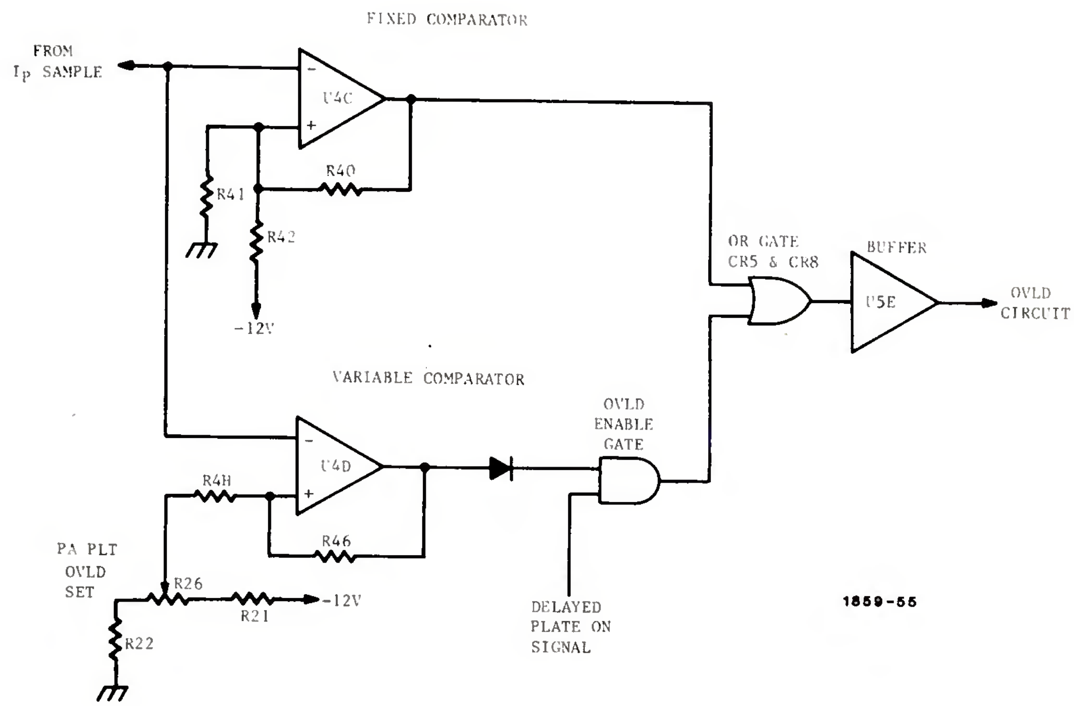


Figure 4-16. Simplified Plate Current Overload

exceeds the pre-set trip point the comparator output goes HIGH and is applied to the plate current overload enable gate. The second HIGH input to the enable gate is the delayed plate on signal. If the delay time has elapsed the overload signal is applied to the appropriate SCR through the plate overload OR gate. The enable gate prevents any initial turn on surge of plate current from tripping the plate overload circuits.

4-108. The screen overload circuits operate in an identical manner as the plate overload with the fixed comparator set to have an output at 900 mA screen current.

4-109. MULTIMETER CIRCUITS. The multimeter, M2, monitors screen voltage and current, grid bias voltage and current, or filament voltage. In figure 4-15 the multimeter is shown as it electrically appears in the circuit with the parameter being monitored inside the meter circle. It should be remembered that the crossed lines indicate multimeter switch contacts and that the multimeter is not in the circuit unless the meter switch indicates that position.

4-110. Screen Circuits. Resistors R22 and R23 are used as meter multipliers and R26 as a shunt for the multimeter in the SCREEN VOLTAGE switch position. In the SCREEN CURRENT switch position, R23 is used as a multiplier for the meter, while CR1 provides meter protection. The meter is used to monitor current in the negative lead of the screen power supply. A sample for the screen current overload circuit is provided through resistor R20.

4-111. Bias Circuits. The BIAS VOLTAGE switch position monitors grid bias voltage at the center tap of transformer T6. Resistor R24 is a meter multiplier and resistor R25 is the meter shunt. Resistor R1 and R10 serve as the same functions respectfully when the switch indicates BIAS CURRENT.

4-112. Filament Circuits. When the multimeter switch is in the FILAMENT VOLTAGE position the multimeter is connected in series with the V output of integrated circuit U1 and an offset voltage. The offset voltage gives the meter an expanded scale of 7 to 12 volts AC. The output voltage of U1 is a dc voltage, which corresponds to the true RMS voltage input of U1 regardless of the waveform shape. Input voltage for U1 is developed across the voltage divider consisting of R1 in the transmitter cabinet and R2 on the ac control board. It should be noted that the return lead of R2, U1, and other components associated with the filament voltage meter circuit are connected to the ground potential side of the power amplifier tube cathode. In this manner the dc voltage out of the integrated circuit represents the true RMS voltage of the filament. Resistors R5 and R6 are a voltage divider furnishing -V to U1, while the divider R7 and R8 provide +V to the integrated circuit. The offset voltage is present whenever the filament voltage is present. The coils and capacitors not shown in the simplified schematic 4-15 are used to prevent rf voltage from effecting the meter indication.

SECTION V

MAINTENANCE

5-1 INTRODUCTION

5-2. This section provides preventive maintenance checks, cleaning, and corrective maintenance information.

5-3. PURPOSE

5-4. The information contained in this section is intended to provide guidance to establish a comprehensive maintenance program to promote operational readiness and eliminate down time. Particular emphasis is placed on preventive maintenance and record keeping functions.

5-5. STATION RECORDS

5-6. The importance of keeping station performance records cannot be overemphasized. Separate logbooks should be maintained by operation and maintenance activities. These records can provide data for predicting potential problem areas and analyzing equipment malfunctions.

5-7. TRANSMITTER LOGBOOK

5-8. As a minimum performance characteristics, the transmitter should be monitored (using front panel indicators) and the results recorded in the transmitter logbook at each shift change or at least once per day.

5-9. MAINTENANCE LOGBOOK

5-10. The maintenance logbook should contain a complete description of all maintenance activities required to keep the transmitter operational. A list of maintenance information to be recorded and analyzed to provide a data base for a failure reporting system is as follows:

DISCREPANCY	Describe the nature of the malfunction. Include all observable symptoms and performance characteristics.
CORRECTIVE ACTION	Describe the repair procedure used to correct the malfunction.
DEFECTIVE PART(S)	List all parts and components replaced or repaired. Include the following details: a. COMPONENT TIME IN USE b. COMPONENT PART NUMBER c. COMPONENT SCHEMATIC NUMBER d. COMPONENT ASSEMBLY NUMBER e. COMPONENT REFERENCE DESIGNATOR

WARNING: Disconnect primary power prior to servicing.

SYSTEM ELAPSED TIME	Total transmitter time on.
NAME OF REPAIRMAN	Person who actually made the repair.
STATION ENGINEER	Indicates chief engineer noted and approved the transmitter repair.

5-11. SAFETY PRECAUTIONS

5-12. It is very dangerous to attempt to make measurements or replace components with power on. The design of the transmitter provides safety features such that if the cabinet is opened while power is applied, an interlock switch will remove all transmitter and exciter primary ac potentials. However, ac line potentials exist within the chassis even if the interlock operates. Therefore, the primary ac disconnect should be opened prior to servicing the unit.

5-13. Do not short out or bypass interlock switches as a maintenance short cut. Module removal or replacement with power energized is not recommended.

5-14. PREVENTIVE MAINTENANCE

5-15. Preventive maintenance is a systematic series of operations performed periodically on equipment. As these procedures cannot be applied indiscriminately, specific instructions are necessary.

a. Visual inspection is the most important preventive maintenance operation because it determines the necessity for the others. Become thoroughly acquainted with normal operation conditions in order to recognize and identify abnormal conditions readily. The remedy for most visible defects is obvious, however care must be taken if heat damaged components are located. Overheating is usually a symptom of trouble. It is essential to determine the actual cause of overheating before the heat damaged component is replaced, otherwide the damage may be repeated. Inspect for:

   1. Overheating, indicated by discoloration, bulging parts and peculiar odors.

   2. Leakage of grease and oil.

   3. Oxidation.

   4. Dirt, corrosion, rust, mildew and fungus growth.

b. Check parts for overheating, especially rotation parts such as the blower motor. The need for lubrication, the lack of proper ventilation, or the existence of some defect can be detected and corrected before serious trouble occurs. Become familiar with operating temperatures in order to recognize deviations from the normal range.

c. Tighten loose screws, bolts, and nuts. Do not tighten indiscriminately as fittings that are tightened beyond the pressure for which they are designed may be damaged or broken.

d. Clean parts when inspection shows that cleaning is required.

e. Make adjustments when inspection shows that adjustments are necessary to maintain normal operation.

f. Lubricate meshing mechanical surfaces at specified intervals with specified lubricants to prevent mechanical wear and keep the equipment operating normally. Do not over lubricate.

g. Paint surfaces with the original type of paint (use prime coat if necessary) when inspection shows rust, worn or broken paint film.

5-16. FILTER CLEANING

5-17. One filter is provided in the back of the FM-25K cabinet. Clean each filter periodically with warm water and a mild detergent with replacement done on an as-needed basis. Additional filters may be ordered from Harris to assist in maintenance (Harris Part No. 839-7436-001).

CAUTION

DO NOT OIL THE FILTER. THE FILTER WILL CLOG IF OILED. THE AIR FILTER IS TO BE INSTALLED DRY.

5-18. BLOWER MAINTENANCE

5-19. Inspect the blower for dust accumulation periodically. Remove the dust with a vacuum cleaner and brush. Check the impeller for wear. The motor bearings are sealed and lubricated for approximately 25,000 hours of operation in an environment of 120^{o}F (49.89^{o}C). A blower that is noisy or shows wear will require bearing replacement or unit replacement. The blower mounting bolts should be checked for tightness.

5-20 Each blower motor is cooled by the air passing over the motor. If the ambient air temperature is too high or the air flow is restricted, then the lubricant will gradually be vaporized from the motor bearings and bearing failure will occur. If very dirty air passes over the motor, the accmulation must be wiped from the motor and the dust must be blown out of the motor before the collection of dust impairs the motor cooling.

5-21. If the unit is operated to move very dusty air, the concave side of the impeller blades will collect this dust and the material will build up on the surface. If this happens, the performance will be reduced and unbalance will result with a possibility of damage to the motor.

5-22. MAINTENANCE OF COMPONENTS

5-23. The following paragraphs provide information for component maintenance.

5-24. SEMICONDUCTORS. Routine checking of semiconductors used in the FM-25K is not required. The best check of semiconductor performance is actual operation in the transmitter. When semiconductors are replaced, check circuitry operation which may be affected. Replacement semiconductors should be of the original type or a recommended direct replacement. Preventive maintenance of transistors is accomplished by performing the following steps:

a. Inspect the semiconductors and surrounding area as accumulations of dirt or dust could form leakage paths.

b. Examine all semiconductors for loose connections or corrosion.

5-25. CAPACITORS. Preventive maintenance of capacitors is accomplished as follows:

a. Examine all capacitor terminals for loose connections or corrosion.

b. Ensure that component mountings are tight.

c. Examine the body of each capacitor for swelling, discoloration, or other evidence of breakdown.

d. Inspect oil-filled and electrolytic capacitors for leakage signs.

e. Use standard practices to repair poor solder connections with a low-wattage soldering iron.

f. Clean cases and bodies of all capacitors.

5-26. FIXED RESISTORS. Preventive maintenance of fixed resistors is accomplished by the following steps:

a. When inspecting a chassis, printed circuit board, or discrete component assembly, examine resistors for dirt or signs of overheating. Discolored, bulging, cracked, or chipped components indicate a possible overload.

b. When replacing a resistor ensure the replacement value corresponds to the component designated by the schematic diagram.

c. Clean dirty resistors with a small brush.

5-27. VARIABLE RESISTORS. Preventive maintenance of variable resistors follows:

a. Inspect and tighten all loose mountings, connections and control knob setscrews (do not disturb knob alignment).

b. If necessary, clean components with a dry brush or cloth.

c. When dirt is difficult to remove, clean with a cloth moistened with cleaning solvent.

5-28. TRANSFORMERS. Preventive maintenance of transformers is accomplished by performing the following:

a. Feel each transformer soon after power removal for signs of overheating.

b. Inspect each transformer for dirt, loose mounting brackets and rivets, loose terminal connections, and insecure connecting lugs. Dust, dirt or moisture between terminals may cause flashovers. Insulating compound or oil around the base of a transformer indicates overheating or leakage.

c. Tighten loose mounting lugs, terminals, or rivets.

d. Clean with a dry cloth. Use cleaning solvent if required.

e. Clean corroded contacts or connections with No. 0000 sandpaper.

f. Replace defective transformers.

5-29. FUSES. Preventive maintenance with reference to fuses is accomplished as follows:

a. When a fuse blows, determine the cause before installing a replacement.

b. Inspect fuse caps and mounts for charring and corrosion.

c. Examine fuse clips for dirt, improper tension, and loose connections.

d. If necessary tighten fuse clips and connections to the clips. The tension of the fuse clips may be increased by carefully pressing the clip sides together.

e. Dust fuses and clips with a small brush.

5-30. METER. Preventive maintenance of the meter is accomplished as follows:

a. Inspect meters for loose, dirty, or corroded mountings and connections.

b. Examine leads for frayed insulation and broken strands.

c. Check for cracked or broken plastic cases and cover glasses.

d. Tighten loose mountings or connections. Since meter cases are made of plastic, exercise care to prevent breakage.

e. Clean meter cases and glass cover with a dry cloth.

f. Remove dirt from mountings and connections with a stiff brush.

g. Remove corrosion with No. 0000 sandpaper.

5-31. RELAYS. Replace hermetically sealed relays if defective. Non-hermetically sealed relays are considered normal if:

a. The relay is mounted securely.

b. Connecting leads are not frayed and the insulation is not damaged.

c. Terminal connections are tight and clean.

d. Moving parts travel freely.

e. Spring tension is correct.

f. Contacts are clean, adjusted properly and made good contact.

g. The coil shows no signs of overheating.

h. The assembly parts are clean and not corroded.

5-32. SWITCHES. Preventive maintenance of switches is accomplished by checking the following:

a. Inspect switches for defective mechanical action or looseness of mounting and connections.

b. Examine cases for chips or cracks. Do not disassemble switches.

c. Inspect accessible contact switches for dirt, corrosion, looseness of mountings and connections.

d. Check contacts for pitting, corrosion, or wear.

e. Operate the switches to determine if each moves freely and is positive in action. In gang and wafer switches, the rotor should make good contact with the stationary member.

f. Tighten all loose connections and mountings.

g. Adjust contact tension.

h. Clean any dirty or corroded terminal connections or switch section with No. 0000 sandpaper.

i. Replace defective switches.

5-33. INDICATORS AND INDICATOR SWITCHES. Preventive maintenance of indicator lamps and indicator switches is accomplished by checking the following:

a. Examine indicator sockets for corrosion and loose hardware.

b. Inspect indicator assemblies for broken or cracked covers, loose envelopes, loose mounting screws, and loose or dirty connections.

c. Tighten loose mounting screws and solder loose connections. If connections are dirty or corroded, clean with No. 0000 sandpaper before soldering.

d. Clean indicators with a dry cloth.

e. Clean corroded socket contacts and connections with No. 0000 sandpaper. Low operating voltages require clean contacts and connections.

5-34. PRINTED CIRCUIT BOARDS. Preventive maintenance of printed circuit boards is accomplished by checking the following:

a. Inspect the printed circuit boards for cracks or breaks.

b. Inspect the wiring for open circuits or raised foil.

c. Check components for breakage or discoloration due to overheating.

d. Clean off dust and dirt with dry compressed air and a brush as required.

e. Use standard practices to repair solder connections with a low wattage soldering iron.

5-35. CORRECTIVE MAINTENANCE

5-36. Corrective maintenance for the transmitter is limited by the objective of minimum down time. Maintainability and care are considerably simplified for operation and maintenance personnel as the transmitter is designed and built with modular circuitry to minimize down time.

CAUTION

DO NOT USE THE EXTENDER BOARD WITH RF INPUT PRESENT TO THE MODULE.

5-37. The FM exciter extender board (939-3524-001) may be used with the FM-25K amplifier modules to check dc voltages. When the board is used with the amplifier, the RF input from the FM exciter must be disconnected from the amplifier and the stenciling on the extender board (UP FOR RF AMP - ONLY) must be oriented to the left. Even though low dc potentials are used on the FM-25K printed circuit boards, servicing equipment with power energized is always hazardous and is therefore not recommended.

5-38. The controller extender board (992-5646-001) may be used to extend the analog or the digital circuit boards from the equipment for maintenance as required. Even though low dc potentials are used on the FM-25K printed circuit boards,, servicing equipment with power energized is always hazardous and is therefore not recommended.

5-39. ADJUSTMENTS

5-40. Table 5-1 provides an adjustment procedure for all controls which are not described in Section II, Installation.

5-41. AIR SWITCH ADJUSTMENT. Air switch S9 is adjusted for proper operation as follows:

a. Ensure that the following circuit breakers and switches are set to OFF.

   1. Station power distribution breaker to the high voltage power supply.

   2. Station power distribution breaker to the transmitter cabinet.

   3. Both circuit breakers on the high voltage power supply.

   4. All circuit breakers on the transmitter front panel.

b. Open the transmitter cabinet rear door and locate air switch S9 (reference 2 in figure 3-2).

c. Rotate the adjustment screw on S9 to the extreme counterclockwise position.

d. Rotate the adjustment screw on S9 one complete turn in the clockwise direction.

e. Loosen the captive retaining hardware on the bottom one-half of the PA tube access door.

f. Close the transmitter cabinet rear door.

g. Set the station power distribution breaker that provides power to the transmitter cabinet to the ON position.

WARNING

230 VAC IS NOW PRESENT IN THE TRANSMITTER CABINET AND THE CONTROL SECTION OF THE HIGH VOLTAGE POWER SUPPLY.

h. On the transmitter front panel set the BIAS and BLOWER circuit breakers to ON.

i. Depress the FILAMENT ON pushbutton; let the blower build up speed and verify the AIR INTERLOCK indicator is extinguished.

j. Depress the FILAMENT OFF pushbutton and open the transmitter cabinet rear door.

k. Rotate the adjustment screw on S9 one quarter turn clockwise and close transmitter cabinet rear door.

l. Repeat steps i. through k. until the AIR INTERLOCK indicator illuminates with the blower operating at full speed.

m. Open the transmitter cabinet rear door and secure the captive retaining hardware on the PA access door loosened in step e.

n. Close the transmitter cabinet rear door and depress the FILAMENT ON pushbutton.

o. Verify the AIR INTERLOCK indicator is extinguished after the blower builds up speed.

p. This completes the air switch adjustment procedure.

5-42. COMPONENT REPLACEMENT

5-43. Figures 5-3 through 5-12 identify the components on the circuit boards by symbol number. Figure 5-13 identifies the components on the Plate Blocker Assembly, while figure 5-14 identifies the components mounted beneath the tube socket deck. The circuit boards used in the FM-25K are of the double-sided plated-through type. This means that there are traces on both sides of the board and the through-holes contain a metallic plating. Because of the plated-through holes, solder creeps up into the hole. This requires a more sophisticated technique for component removal in order to avoid damage to the traces on the board. Excessive heat of any point on the board will cause damage.

5-44. To remove a component from a double-sided board, the leads of the defective component should be cut from the body while the leads are still soldered to the board. The component is then discarded and each lead is heated independently and pulled out of the hole. Each hole may then be cleared of solder by carefully heating with a low wattage iron and removing the residual solder with a solder vacuum tool.

5-45. The new component is installed in the usual way and soldered from the bottom side of the board. If no damage has been done to the plated-through hole, soldering on the top side is not required. However, if the removal procedure did not progress smoothly, each lead should be soldered at the top side to prevent potential intermittent problems.

5-46. After soldering, remove residual flux. Solvents are available in electronic supply houses which are useful. The board should then be checked to ensure the defluxing operation has removed the flux and not just smeared it about so that it is less visible. While rosin flux is not normally corrosive, it will absorb moisture and become conductive enough to cause deterioration in specifications over a period of time.

5-47. SCREEN BLOCKER REPLACEMENT. The screen blocker may be field replaced as follows:

a. Remove all power from the transmitter.

b. Remove the power amplifier tube following the procedure in paragraph 5-49.

CAUTION

DO NOT DAMAGE THE TUBE SOCKET FINGER STOCK DURING TUBE REMOVAL.

c. Remove the power amplifier cavity rear panel (27 screws with captive nuts).

d. On the underside of the tube socket deck, remove the screen dc connection from left rear feed through insulator.

e. Remove the cap nuts and associated hardware from all four corners of the screen bypass plate.

NOTE

The hardware associated with the screen dc connection is threaded into the screen bypass plate and must be removed from the underneath side.

f. Remove the screen bypass plate being careful not to damage the screen fingerstock.

g. Remove the Kapton screen insulator.

h. Ensure the PA tube socket deck is clean and free of foreign matter. (This point can not be over-emphasized.)

i. Replace the Kapton screen insulator (3 mil). The insulator should be clean and free of foreign matter.

j. Ensure that the bottom side of the screen bypass plate is clean. Set the screen bypass plate in position over the insulator.

k. Replace the corner screen bypass plate mounting hardware finger tight. (The screen bypass plate should be free to move.) Do not connect to screen dc lead at this time.

l. Insert the PA tube following the instructions of paragraph 5-53. The tube will act as a gauge and align the screen bypass plate in the correct position.

m. Tighten the corner mounting hardware on the screen bypass plate and install the cap nuts.

n. Using a VOM on the RX100 scale verify that the screen bypass plate is not shorted to ground.

o. Reconnect the screen dc lead to the left rear corner.

p. Reinstall the cavity rear panel using the original hardware. This completes the screen blocker replacement.

5-48. PLATE BLOCKER REPLACEMENT. Maintenance personnel should use their own judgement in repairing the plate blocker assembly. The placement of the "Kapton" ployimide film is highly critical. The upmost care and proper handling should be observed. It is recommended that the maintenance man familiarize himself with the physical properties of "Kapton" by studying the appropriate service bulletins in the appendix of this book. The plate blocking assembly (Harris part number 929-4129-001) as an entire assembly that can be obtained from the Harris Service Parts Department. If plate blocker assembly repair is required it can be accomplished in the following manner:

a. Ensure all ac power is removed from the transmitter.

b. Remove the power amplifier tube following the instructions in paragraph 5-49.

c. Remove the PA cavity back panel held by 27 screws with captive nuts.

NOTE

Be sure to mark the set of holes holding the shorting deck in the next step so that the deck can be replaced in the same position.

d. While holding the cavity shorting deck (ensure it doesn't fall), remove the 15 screws securing the shorting deck to the cavity sides.

e. Carefully remove the plate blocking assembly and shorting deck from the cavity.

f. Place the removed assembly on a clean work bench.

g. Loosen the clamp holding the plate blocking assembly to the shorting deck.

h. Slide the blocking assembly out of the shorting deck.

NOTE

In the following steps refer to figure 5-13.

i. Loosen the clamp assembly holding the inner and outer tubes.

j. Remove the six sets of mounting hardware on the strap connecting the outer tube halves.

k. Carefully slide the inner and outer tubes apart.

l. Remove the old "Kapton" from the inner tube.

m. Wrap five turns of new "Kapton" (Harris part number 033-4010-010) around the inner tube; ensure that the edge of the "Kapton" is 0.81 inches from the edge of the inner tube as shown in figure 5-13. Also ensure no air pockets exist between layers.

n. Being careful not to damage the "Kapton" slide the outer tube over the inner tube until the edge of the outer tube is 1.8 inches from the edge of the inner tube.

o. Temporarily slide the clamp assembly up 4.5 inches from the edge of the assembly and tighten the clamp.

p. Install the strap removed in step j. and tighten the hardware.

q. Loosen the clamp from its temporary position; slide it down to the end of the outer tube and tighten.

r. Verify the dimensions on the plate blocking assembly as shown in figure 5-13.

s. Use a VOM on its resistance scale to verify that the two tubes are not shorted electrically.

NOTE

If a HI-POT machine is available, the plate blocker should be tested at 15 kV dc for two minutes.

t. Slide the plate blocking assembly into the shorting deck; secure the clamp.

u. Install the deck assembly into the cavity; making sure to use the same mounting holes. Secure with the proper hardware.

v. Replace the back cover of the cavity using the correct hardware.

w. Install the tube following the instructions of paragraph 5-53.

5-49. TUBE REMOVAL AND INSTALLATION

5-50. The following paragraphs provide information for proper PA tube removal and installation.

5-51. PA TUBE REMOVAL. Prior to PA tube removal it is recommended that personnel read and study the entire procedure before attempting tube removal. In instances where the transmitter is operating on a higher frequency, it can not be over emphasized that the proper removal sequence must be followed in order to prevent damage to the tube or the tube socket fingerstock. The PA tube may be removed in the following manner:

a. Ensure all power is removed from the transmitter.

b. Rotate the PA TUNE control to the MAX position (extreme clockwise position).

NOTE

Always use the front panel control PA TUNE to place the tuning control in the maximum position.

c. Open the transmitter cabinet rear door.

d. Use the shorting stick to discharge all capacitors.

e. Remove the PA access door held by 12 captive screws.

f. Use the shorting stick to ensure that no residual voltages are present.

NOTE

The next step will determine which sequence must be used in removing the tube. On certain higher frequencies, the sequence in step (h.) is the only way the tube can be removed.

g. Refer to the top pictorial of figure 5-1. On the transmitter cavity back panel locate the hardware used to mount the cavity shorting deck. Counting from the bottom set of mounting holes, determine which set of holes is being used to support the cavity shorting deck.

NOTE

If the cavity shorting deck is supported in one of the four bottom sets of mounting holes, the sequence in step (h.) must be used to remove the tube. If the shorting deck is supported above the four bottom sets of mounting holes, the sequence in step (i.) may be used for tube removal.

h. The following sequence is to be used if the cavity shorting deck is supported in the bottom four sets of mounting holes:

CAUTION

PRIOR TO LOOSENING ANY OF THE CLAMPS STUDY THE TOP PICTORIAL OF FIGURE 5-1. UNDER NO CIRCUMSTANCES SHOULD THE STATIONARY PLATE CLAMP BE LOOSENED.

NOTE

Refer to figure 5-1. The sequence numbers on the pictorials coincide with the steps in the following sequence.

1. Loosen the anode clamp; slide the clamp down resting it on the screen blocker assembly.

2. Loosen the top clamp; slide the clamp down allowing it to rest on the stationary tuning plate.

3. Raise the plate blocking assembly until the stationary tuning plate prevents the blocking assembly from sliding any further into the cavity short; hold the blocking assembly in the raised position.

CAUTION

IN THE FOLLOWING STEP, ENSURE THE TOP CLAMP IS TIGHT AND WILL PREVENT THE BLOCKING ASSEMBLY FROM SLIDING DOWN AND CAUSING DAMAGE.

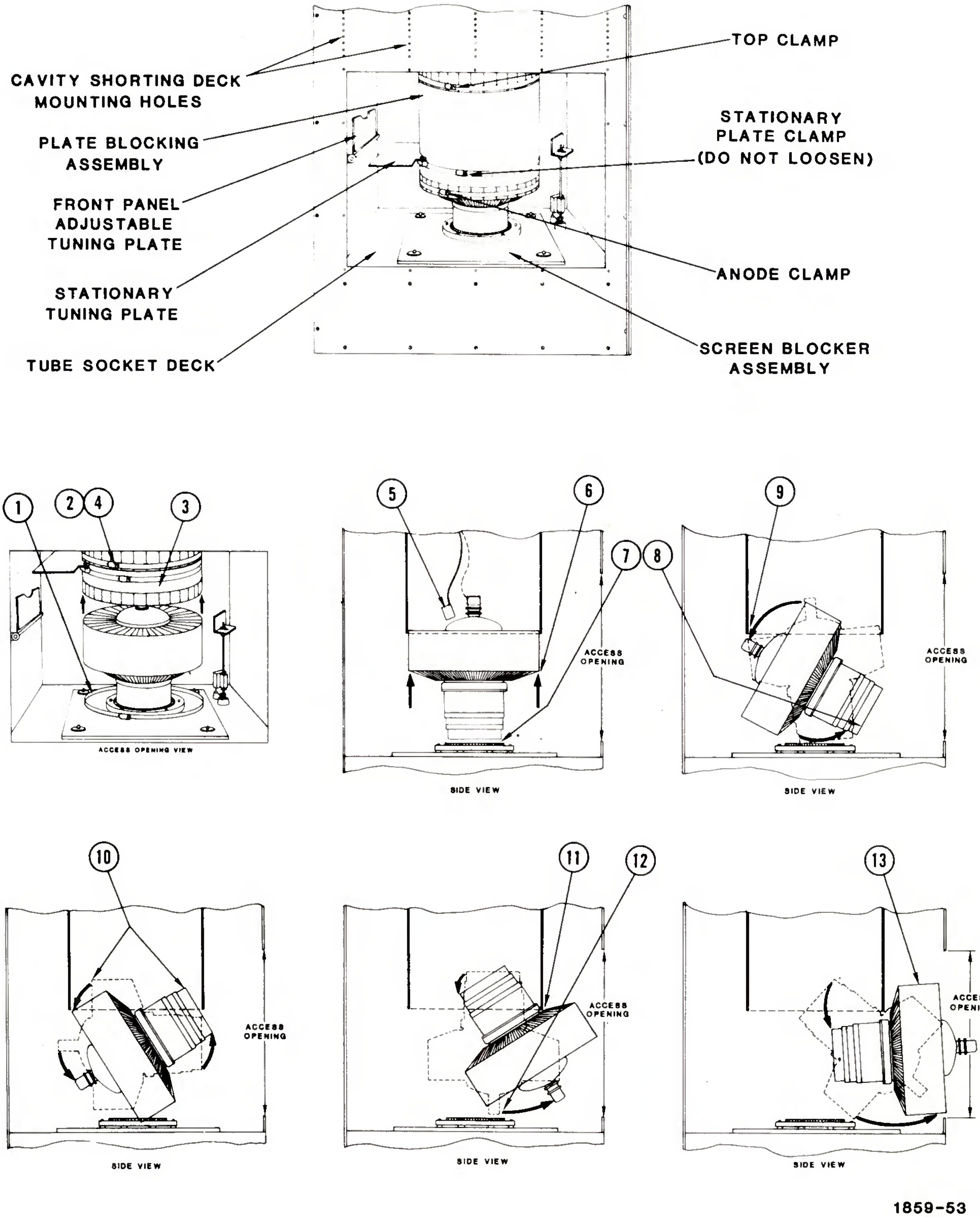


Figure 5-1. PA Tube Removal

4. While holding the plate blocking assembly in the raised position, slide the top clamp up over the fingerstock protruding from the cavity short and tighten; ensure the clamp is holding the plate blocking assembly in the short.

5. Remove the high voltage connector from the tube anode cap. Allow the lead to hang free inside the blocking assembly.

6. Place both hands beneath the anode of the tube. (Be careful not to place thumbs on the top of the tube.) Rest elbows on the tube socket deck and exert an upward force on the tube until the tube is free of the socket.

CAUTION

DO NOT ROCK OR ROTATE THE TUBE WHILE THE TUBE IS ENGAGED IN THE SOCKET OR DAMAGE WILL OCCUR TO THE FINGERSTOCK.

7. Lift the tube until the filament stem is clear of the socket assembly.

NOTE

In the following steps ensure that the tube does not drop into the socket assembly and damage the fingerstock.

8. Rotate the filament stem towards the access opening; ensure the stem does not damage the fingerstock.

9. Continue rotating the tube until the filament stem is pointing directly to the access opening. The anode cap must clear the far edge plate blocking assembly.

NOTE

The tube should now have been turned 90 degrees from its original position.

10. While maintaining the tube positioned over the tube socket, rotate the filament stem towards the top of the cavity; guide the anode past the far edge of the blocking assembly and the filament stem past the near edge of the blocking assembly into the blocking assembly.

NOTE

Depending on the height of the cavity shorting deck, the anode may dip into tube socket during this turn. Be careful not to damage the exposed fingerstock.

NOTE

The tube should now have been turned 180 degrees from its original position. The filament stem will be inside the blocking assembly with the tube inverted over the tube socket.

11. While holding the tube in the inverted position, lift it up and towards the access door. The junction of the anode and the tube stem should be touching the edge of the plate blocking assembly nearest the access door.

12. Using the position obtained in step 11. as a pivot point, rotate the anode of the tube towards the access door; ensure the anode clears the socket assembly.

13. Continue rotating the tube until it is 90 degrees from the inverted position. At this time the anode of the tube should be located in the space between the access door and the plate blocking assembly.

14. Carefully guide the tube through the access door and out of the cavity.

i. The following sequence is to be used if the cavity shorting deck is supported in mounting holes above the four bottom sets of mounting holes:

CAUTION

PRIOR TO LOOSENING ANY OF THE CLAMPS STUDY THE TOP PICTORIAL OF FIGURE 5-1. UNDER NO CIRCUMSTANCES SHOULD THE STATIONARY PLATE CLAMP BE LOOSENED.

1. Loosen the anode clamp; slide the clamp down resting it on the screen blocker assembly.

2. Loosen the top clamp; slide the clamp down allowing it to rest on the stationary tuning plate.

3. Raise the plate blocking assembly until the stationary tuning plate is above the top edge of the front panel adjustable tuning plate. Hold the blocking assembly in the raised position.

CAUTION

IN THE FOLLOWING STEP, ENSURE THE TOP CLAMP IS TIGHT AND WILL PREVENT THE BLOCKING ASSEMBLY FROM SLIDING DOWN AND CAUSING DAMAGE.

4. While holding the plate blocking assembly in the raised position, slide the top clamp up over the fingerstock protruding from the cavity short and tighten; ensure the clamp is holding the plate blocking assembly in the short.

5. Remove the high voltage connector from the tube anode cap. Allow the leads to hang free inside the blocking assembly.

6. Place both hands beneath the anode of the tube. (Be careful not to place thumbs on the top of the tube.) Rest elbows on the tube socket deck and exert an upward force on the tube until the tube is free of the socket.

CAUTION

DO NOT ROCK OR ROTATE THE TUBE WHILE THE TUBE IS ENGAGED IN THE SOCKET OR DAMAGE WILL OCCUR TO THE FINGERSTOCK.

7. Lift the tube until the filament stem is clear of the socket assembly.

NOTE

Be careful not to allow the tube to drop into the socket assembly and damage the fingerstock.

8. Carefully guide the tube through the access door and out of the cavity.

5-52. CAVITY CONTACT INSPECTION. It is always good practice whenever a tube has been removed from a socket to inspect contact fingers in the socket for proper tension, cleanliness, and check for broken or bent contact fingers. If a contact finger is missing inspect to insure that the missing finger is not located in such a place as to cause shorting or arcing under normal operations. If a contact finger is slightly bent, gently rebend it to proper position and tension. If a contact finger is badly bend and cannot be straightened, it should be removed from the cavity so that it doesn't break and fall into an electrical circuit. If more than four adjacent contact fingers or more than 30 percent of the total number of contact fingers are missing the entire contact ring should be replaced.

5-53. PA TUBE INSTALLATION. Prior to PA tube installation it is recommended that personnel read and study the entire procedure before attempting to install the tube. In instances where the transmitter is operating on a higher frequency, it can not be over emphasized that the proper installation sequence must be followed in order to prevent damage to the tube or the tube socket fingerstock. The PA tube may be installed in the following manner:

NOTE

The following sequence of instructions assume that maintenance personnel have removed the tube. If this is not the case or if it is an initial tube installation perform steps (a.) through (f.) of paragraph 5-51 before proceeding.

WARNING

ENSURE ALL AC POWER IS REMOVED FROM THE TRANSMITTER.

a. Use a VOM on its resistance scale to ensure that the tube to be installed does not have any elements shorted together and that the filaments are not open.

b. Refer to the top pictorial of figure 5-2. On the transmitter cavity back panel locate the hardware used to mount the cavity shorting deck. Counting from the bottom set of mounting holes, determine which set of holes is being used to support the cavity shorting deck.

NOTE

If the cavity shorting deck is supported in one of the four bottom sets of mounting holes, the sequence in step (c.) must be used to install the tube. If the shorting deck is supported above the four bottom sets of mounting holes, the sequence in step (d.) may be used for tube installation.

c. The following sequence is to be used if the cavity shorting deck is supported in the bottom four sets of mounting holes:

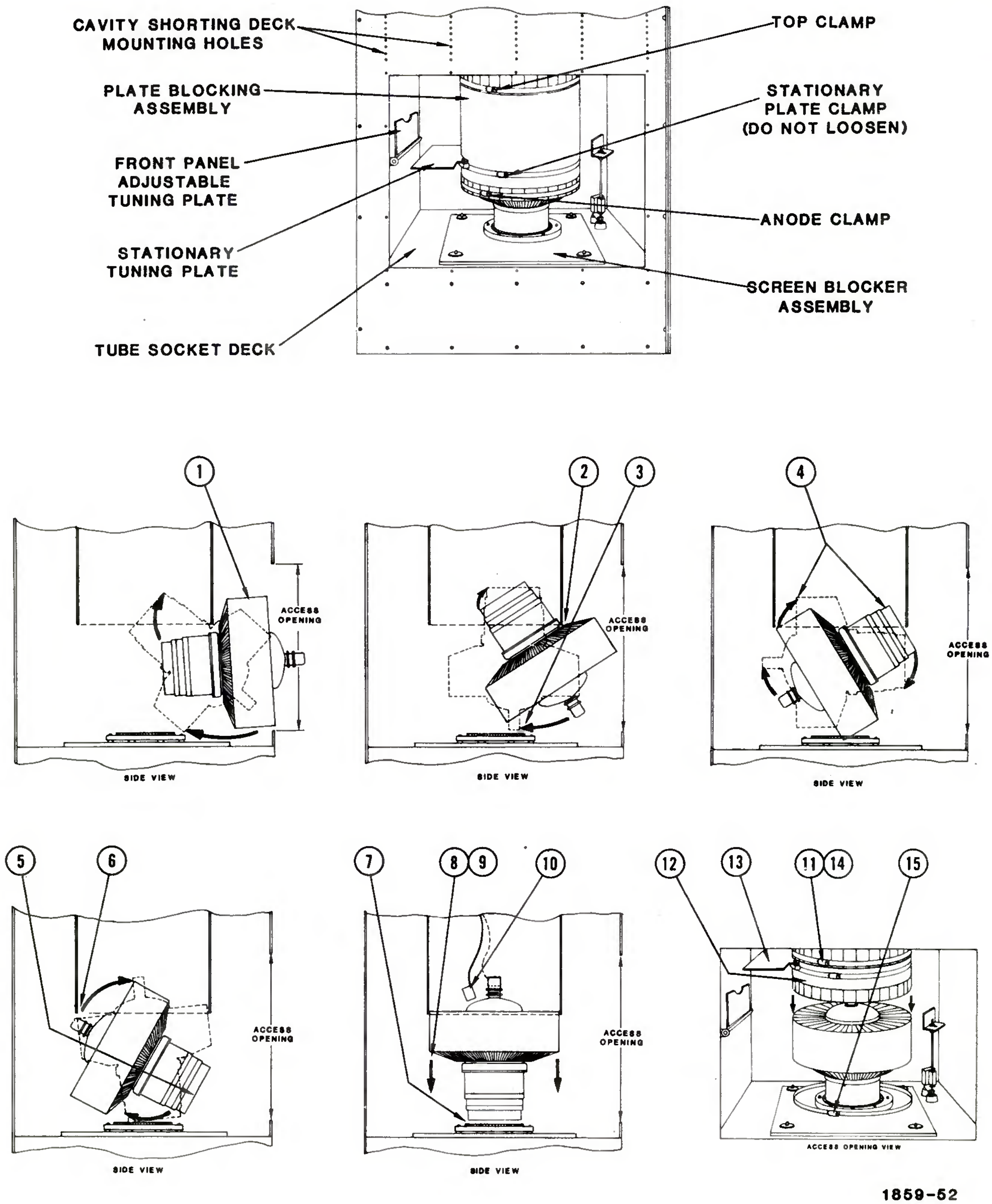


Figure 5-2. Tube Installation

CAUTION

PRIOR TO INSTALLING THE TUBE ENSURE THAT THE TOP CLAMP IS TIGHT AND SECURELY HOLDING THE PLATE BLOCKING ASSEMBLY.

NOTE

Refer to figure 5-2. The sequence numbers on the pictorials coincide with the steps in the following sequence.

1. While holding the tube anode with both hands, guide the tube through the PA access door with the filament stem entering the cavity first.

2. While supporting the tube above the tube socket deck, raise the tube up so that the junction of the anode and the stem is touching the near bottom edge of the plate blocking assembly.

3. Using the position obtained in step (2.) as a pivot point, rotate the filament stem towards the top of the cavity and inside the plate blocking assembly; ensure that the anode cap clears the tube socket.

NOTE

The tube should now be inverted over the tube socket with the filament stem inside the plate blocking assembly. Do not allow the tube to drop into the socket and damage the fingerstock.

4. While supporting the tube over the socket, rotate the filament towards the access opening; guide the stem past the near edge of the blocking assembly and the anode past the far edge of the blocking assembly.

NOTE

Depending on the height of the cavity shorting deck, the anode may dip into the tube socket during this turn. Be careful not to damage the exposed fingerstock.

NOTE

Steps (5.) and (6.) are to be completed simultaneously. Ensure the stem does not damage the fingerstock as the anode swings into the blocking assembly.

5. Rotate the filament stem towards the socket.

6. Guide the anode cap past the far edge of the blocking assembly.

NOTE

The tube should now be in the proper position for insertion, with the anode cap inside the plate blocking assembly.

7. Center the tube over the tube socket.

8. Gently lower the tube into the socket.

CAUTION

DO NOT ROTATE OR ROCK THE TUBE ONCE IT IS INSTALLED IN THE SOCKET OR DAMAGE WILL OCCUR TO THE FINGERSTOCK.

9. Using both hands push the tube straight down until the tube is properly seated.

NOTE

The tube socket has built in stops. Ensure the tube is all the way down in the socket and level.

10. Place the high voltage connector on the anode cap.

IN THE FOLLOWING STEP ENSURE THE PLATE BLOCKING ASSEMBLY IS BEING HELD SECURELY PRIOR TO LOOSENING THE TOP CLAMP.

11. Hold the plate blocking assembly in a secure manner, while loosening the top clamp.

12. Lower the plate blocking assembly over the tube anode until the built in stops prevent further downward motion.

13. Refer to the top pictorial of figure 5-2. Rotate the plate blocking assembly on the tube until the edge of the stationary tuning plate is parallel to the same cavity wall where the front panel adjustable tuning plate is mounted.

14. Ensure the top clamp is up over the fingerstock protruding from the cavity short; tighten the top clamp.

15. Lift the anode clamp off the screen blocker assembly and slide the clamp over the fingerstock at the bottom edge of the plate blocking assembly.

16. Tighten the anode clamp; ensure the clamp is securing the blocking assembly to the tube anode.

17. Proceed to step (e.) to complete the tube installation.

d. The following sequence is to only be used if the cavity shorting deck is supported in mounting holes above the four bottom sets of mounting holes:

1. Holding the tube with both hands, carefully position the tube inside the cavity between the tube socket and the plate blocking assembly with the filament stem down.

2. Center the filament stem over the tube socket.

3. Gently lower the tube into the socket.

CAUTION

DO NOT ROTATE OR ROCK THE TUBE ONCE IT IS INSTALLED IN THE SOCKET OR DAMAGE WILL OCCUR TO THE FINGERSTOCK.

4. Using both hands push the tube straight down until the tube is properly seated.

NOTE

The tube socket has built in stops. Ensure the tube is all the way down in the socket and level.

5. Place the anode clamp (included in installation material) over the anode of the tube; slide the clamp down the tube and allow it to rest on the screen blocker assembly.

6. Attach the high voltage lead to the anode cap.

CAUTION

IN THE FOLLOWING STEP ENSURE THE PLATE BLOCKING ASSEMBLY IS BEING HELD SECURELY PRIOR TO LOOSENING THE TOP CLAMP.

7. Hold the plate blocking assembly in a secure manner, while loosening the top clamp.

8. Lower the plate blocking assembly over the tube anode until the built in stops prevent further downward motion.

9. Refer to figure 5-2. Rotate the plate blocking assembly on the tube until the edge of the stationary tuning plate is parallel to the same cavity wall where the front panel adjustable tuning plate is mounted.

10. Ensure the top clamp is up over the fingerstock protruding from the cavity short.

11. Tighten the top clamp.

12. Lift the anode clamp off the screen blocker assembly and slide the clamp over the fingerstock at the bottom edge of the plate blocking assembly.

13. Tighten the anode clamp ensuring the clamp is securing the blocking assembly to the tube anode.

e. Ensure all loose hardware is removed from inside the cavity.

f. Install the PA access door using the captive hardware.

g. Check the neutralization of the PA tube using the procedure in Section II paragraph 2-40.

5-54. TECHNICAL ASSISTANCE

5-55. HARRIS Technical and Troubleshooting assistance are available from HARRIS Field Service Department 24 hours a day. Telephone 217/222-8200 to contact the Field Service Department or address correspondence to Field Service Department, HARRIS CORPORATION, Broadcast Products Division, P.O. Box 4290, Quincy, Illinois 62305-4290, USA. The HARRIS factory may also be contacted through a TWX facility (910-246-3312) or a TELEX service (40-4347). Prior to starting a troubleshooting procedure check all switches, power cord con- nections, connecting cables, and power fuses.

Table 5-1. RF Circuit Adjustments

CIRCUIT	PURPOSE	VARIABILITY
CAVITY COARSE Tuning	Provides shorted coax to resonate cavity	Raising shorting plate will lower the cavity resonate frequency. Hole patterns in walls and shorting plate give 1/4-inch increments.
PA TUNE (Cavity Fine Tuning)	Tunes the cavity to resonance for limited range of antenna VSWRs	The cavity will tune over +1 MHz range with a 50 ohm load. Rotating front panel adjustment PA TUNE clockwise will tune the cavity higher in frequency. A plate "dip" can be observed and the "efficient side" of resonance should be used.
PA LOAD (C16)	Presents the tube with correct impedance to produce the TPO. Also matches the antenna VSWR	Clockwise rotation for properly tuned cavity will load the cavity heavier and causes more plate current to be drawn.
INPUT TUNE	Matches grid to 50 ohms; capacitor trimmer	When used simultaneously with "Grid Tune", matches the grid impedance to the 50 ohm output impedance of the IPA.
GRID TUNE (L4)	Matches grid to 50 ohms; inductive tuning	When used with "Input Tune", matches the grid impedance to the 50 ohm output impedance of the IPA. Coarse adjust made separately (L7).
IPA OUTPUT POWER ADJ (R31)	Varies the collector supply to the RF amplifier transistors in the IPA. The IPA power then varies accordingly	Range of voltage from 15 volts to 27 volts. Power can be varied from below 100 watts to over 400 watts. Clockwise rotation increases IPA power. The regulated supply to unregulated supply drop should be set for 5 to 8 volts.
GRID VOLTS ADJ (Bias Voltage)	Sets the dc voltage on the grid of the PA tube	Range is from below 250 volts to over 450 volts. Clockwise rotation gives a more negative potential

Table 5-1. RF Circuit Adjustments (Continued)

CIRCUIT	PURPOSE	VARIABILITY
HUM NULL (R33)	Adds a small amount of A/C line voltage to the PA grid. Nulls the residual line hum of other circuits. AM noise reduction.	To be set while observing AM Noise without FM modulation.
POWER OUT-AUTO/MANUAL (1A11S1)	Places the RF power output in control of the operator or under automatic control.	Maintain RF output power to within ±2% or ±4%.
POWER OUT-RAISE/LOWER (1A11S2)	Lower or raises the screen dc voltage.	Range of at least ±100 volts. Will vary output power of transmitter +5% to -15% when properly adjusted.
PA PWR CAL (FWD/REFLD) (1A11R4)	Adjusts loop resistance to calibrated RF output of Tx. Requires calorimeter.	Range of 10 kW to 25 kW output power.
PA REFLECTED POWER CAL (1A11R5)	Adjust loop resistance to calibrated scale to read VSWR. Use voltage of PA forward coupling to set.	Range of 10 kW to 25 kW output power.
IPA PWR CAL FWD (1A11R2)	Adjusts loop resistance to calibrated RF output of IPA. Requires accurate indicating load.	Range scale of 500W maximum.

Table 5-1. RF Circuit Adjustments (Continued)

CIRCUIT	PURPOSE	VARIABILITY
IPA PWR CAL REFLD (1A11R3)	Adjusts loop resistance for IPA reflected power. Use known mismatch power.	Range scale of 50W maximum.
FILAMENT (Voltage) ADJUST (T2)	Adjust filament voltage to 8990. See manufacturers data sheet on 8990.	Range of ±10% or greater. Taps extend this range.

Stripline transmission Line

To RF Pre Driver

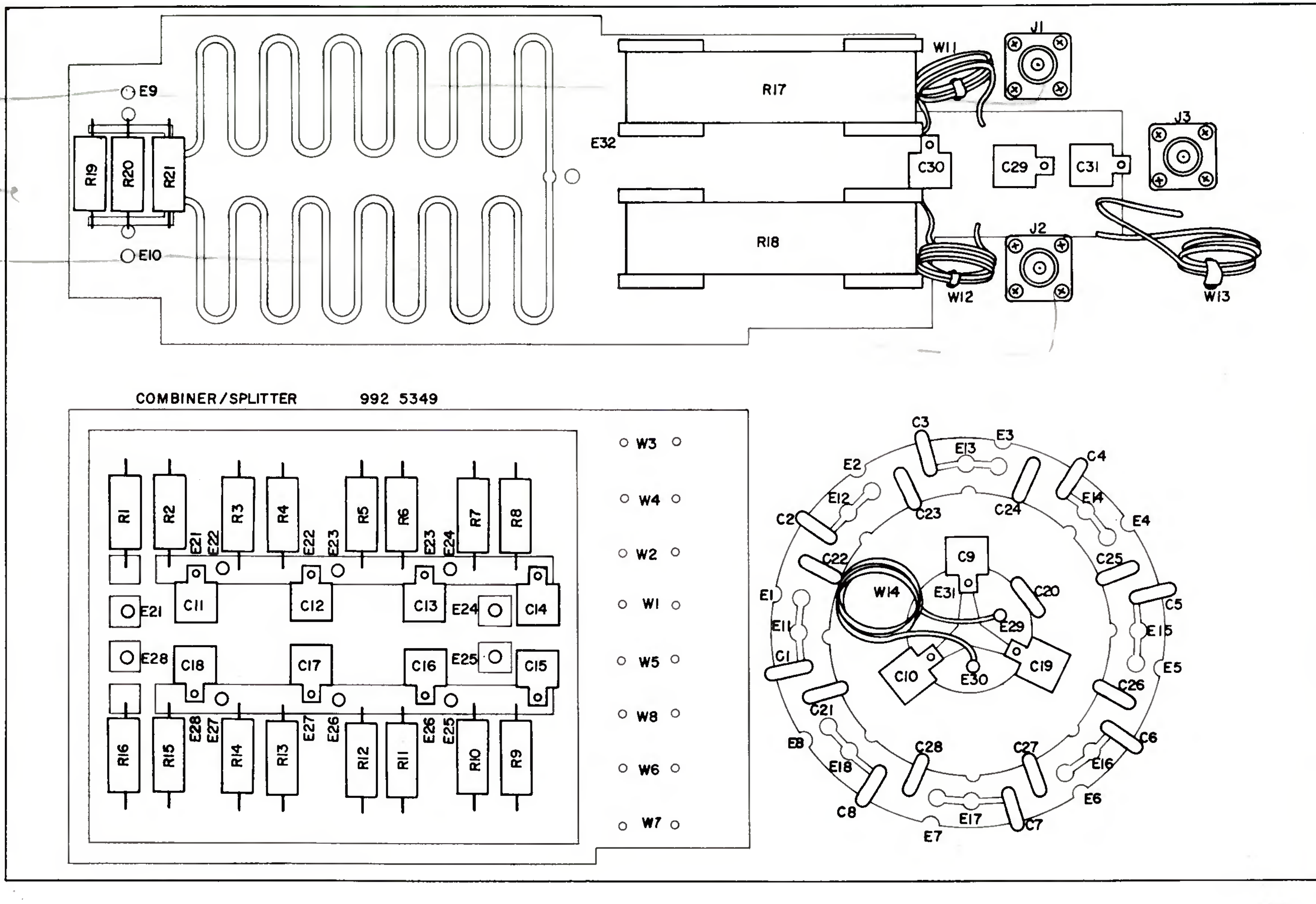


Figure 5-3. Combiner/Splitter Board Component Locator

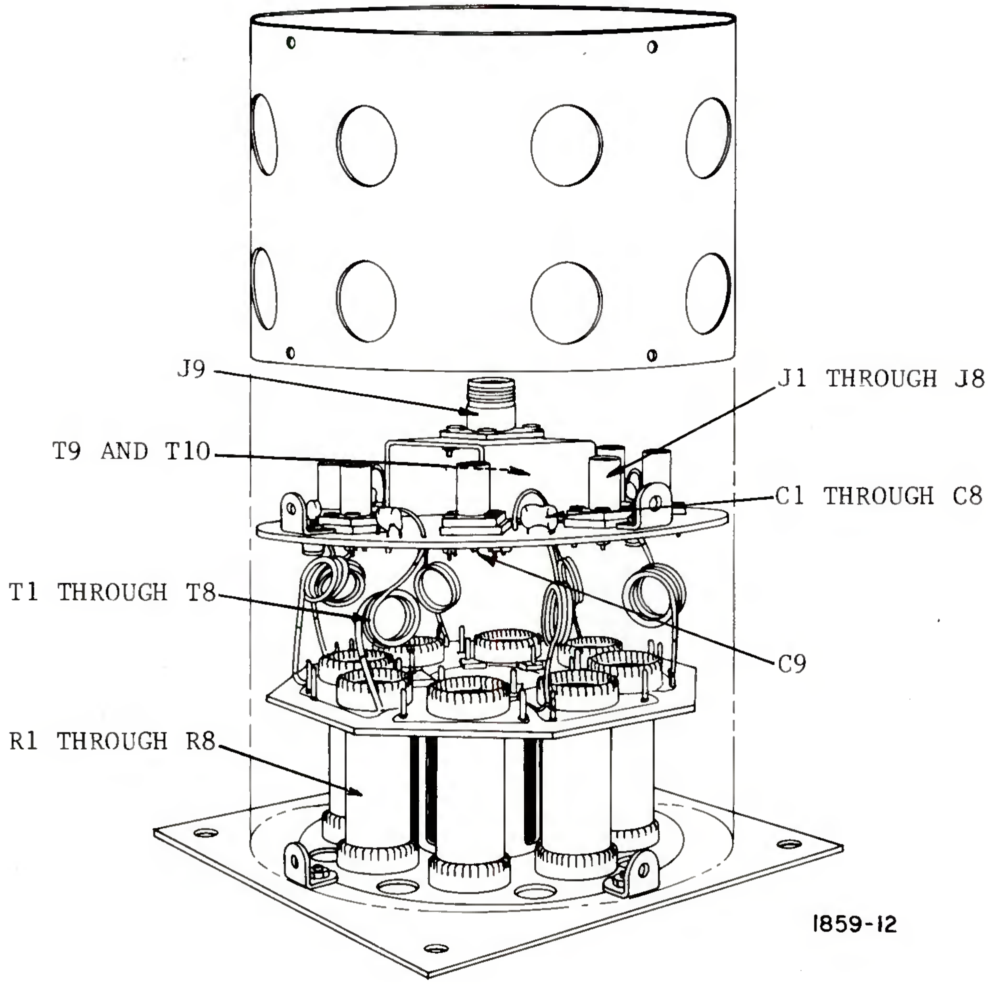
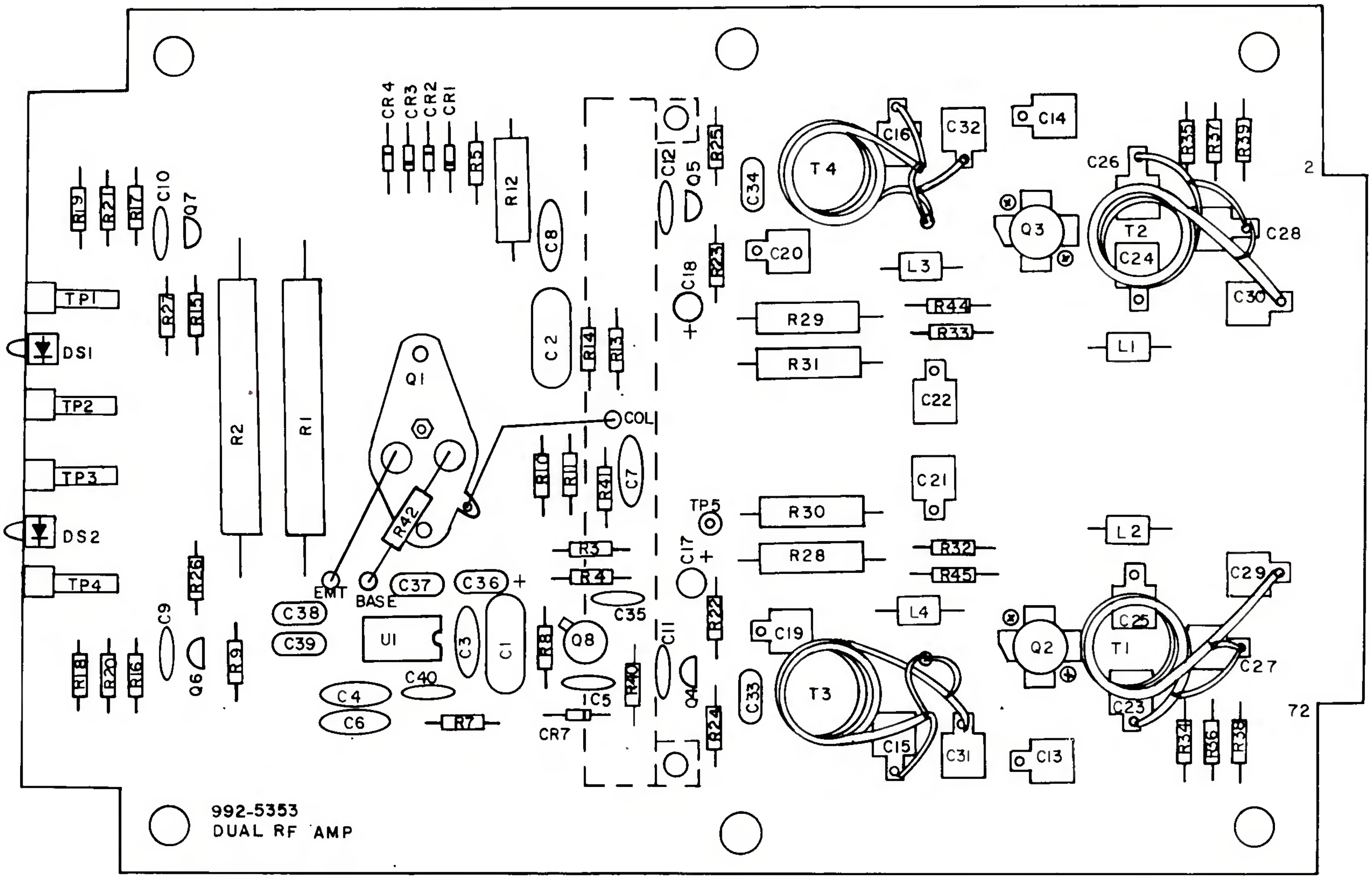


Figure 5-4. Eight Port Combiner Component Locator



1859-6

Figure 5-5. RF Amplifier Module Component Locator

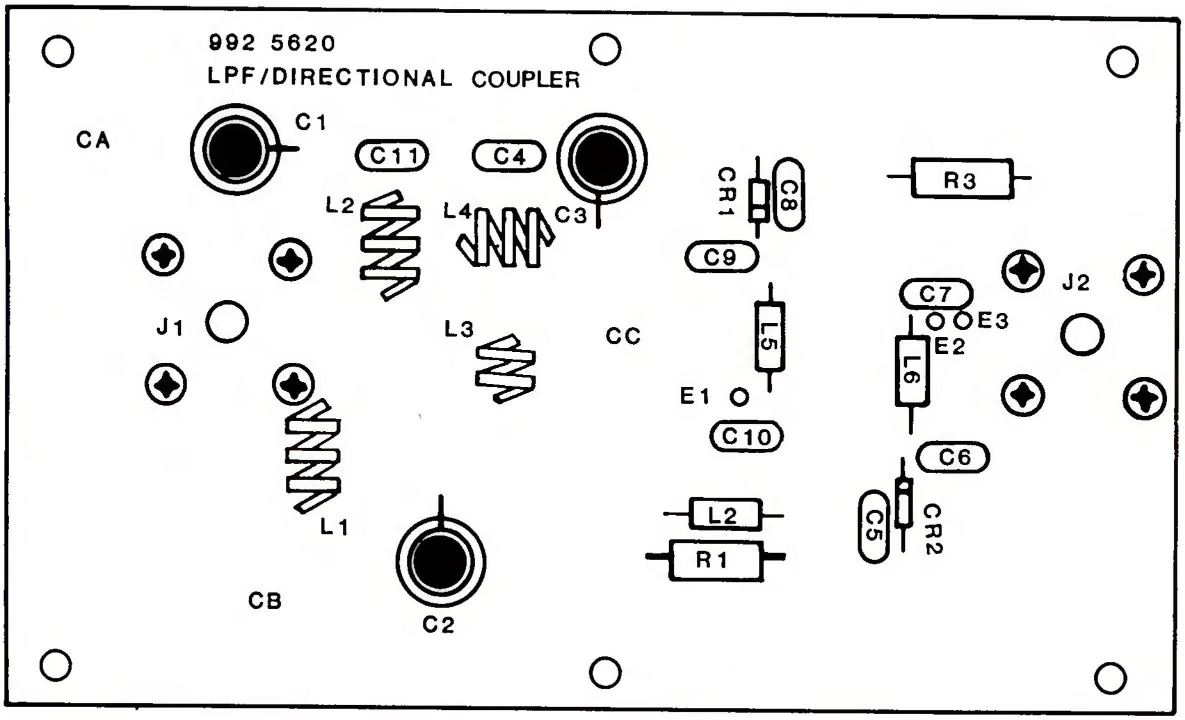
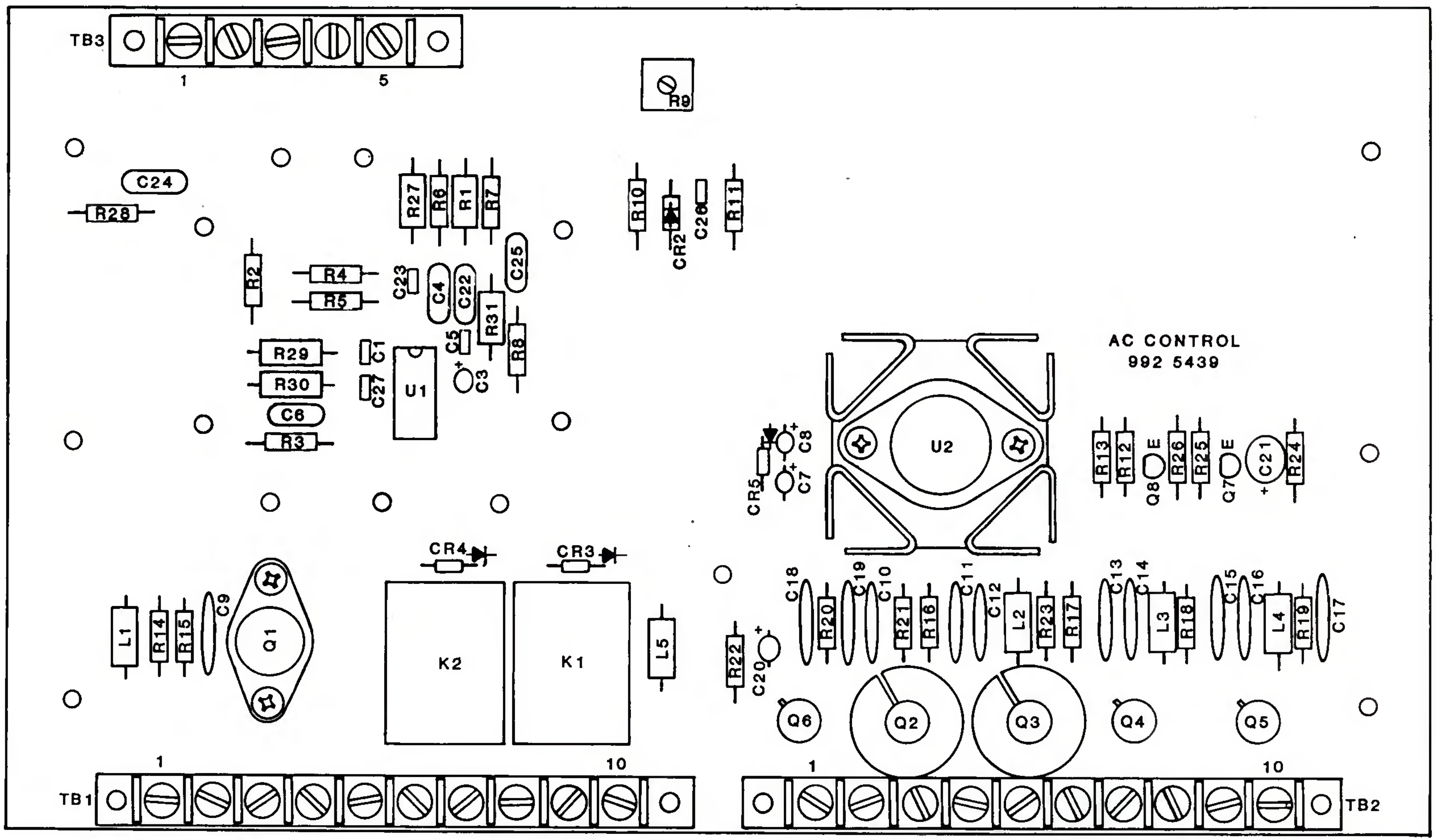


Figure 5-6. IPA Low-Pass Filter/Directional Coupler Board Component Location

WARNING: Disconnect primary power prior to servicing.



1859-21

Figure 5-7. AC Control Circuit Board Component Locator

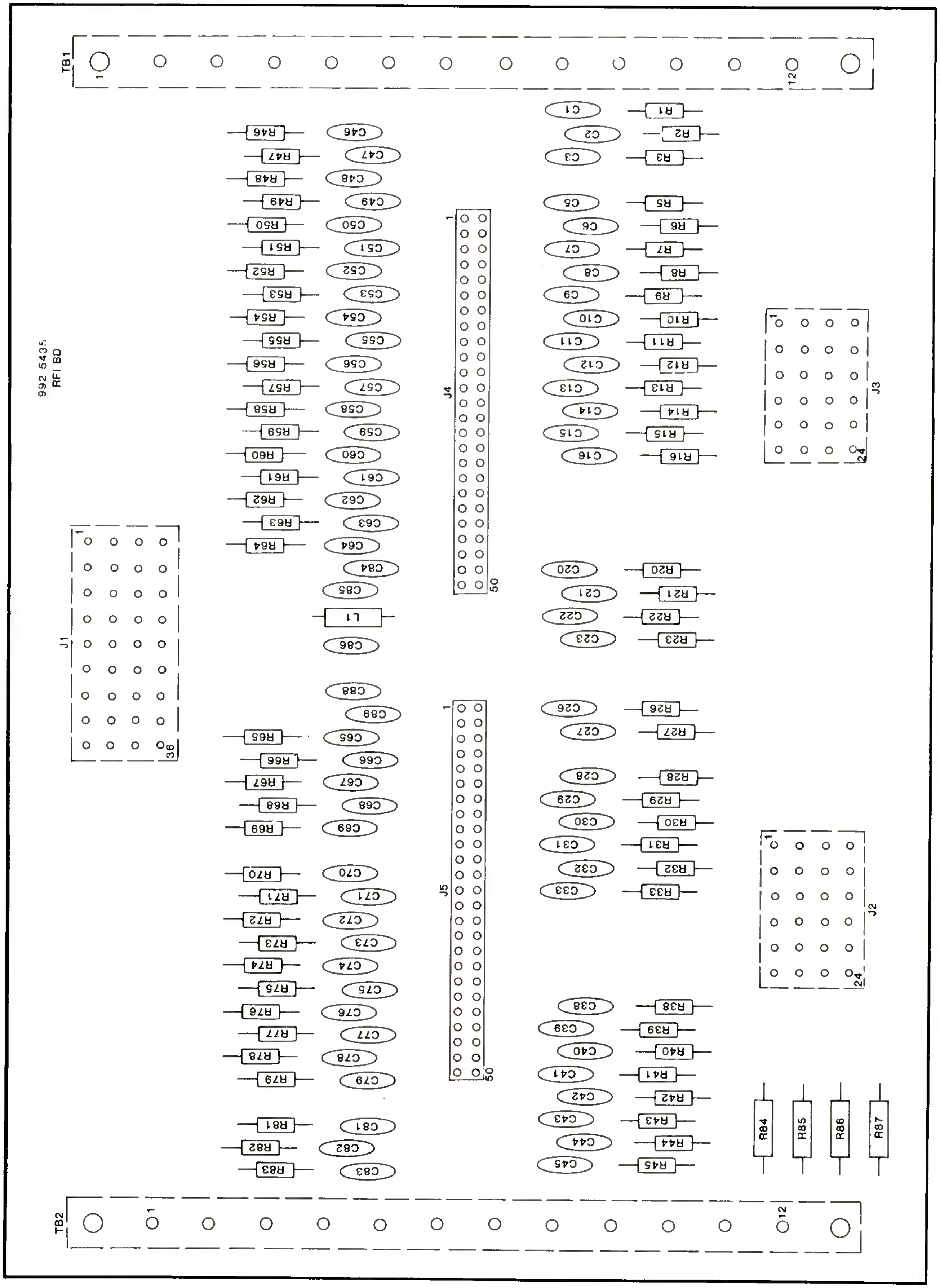
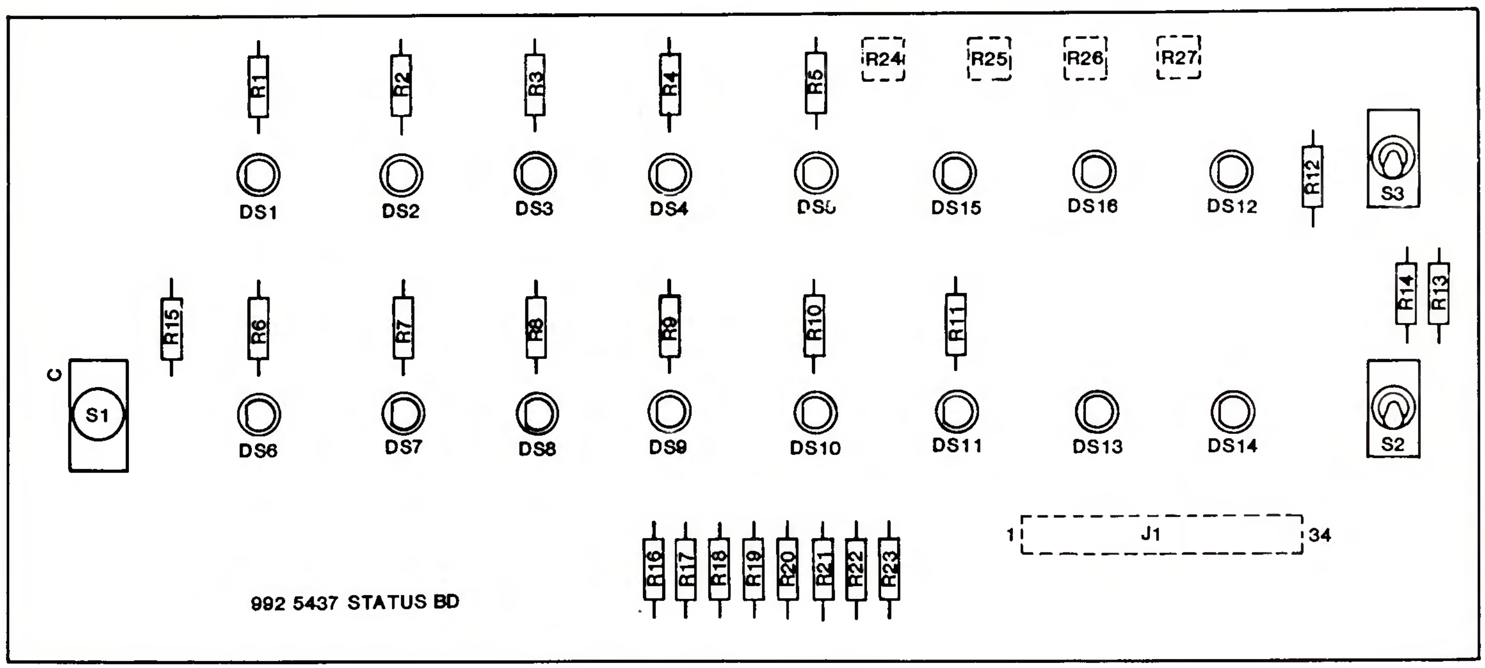


Figure 5-8. Control Logic RFI Board Component Locator

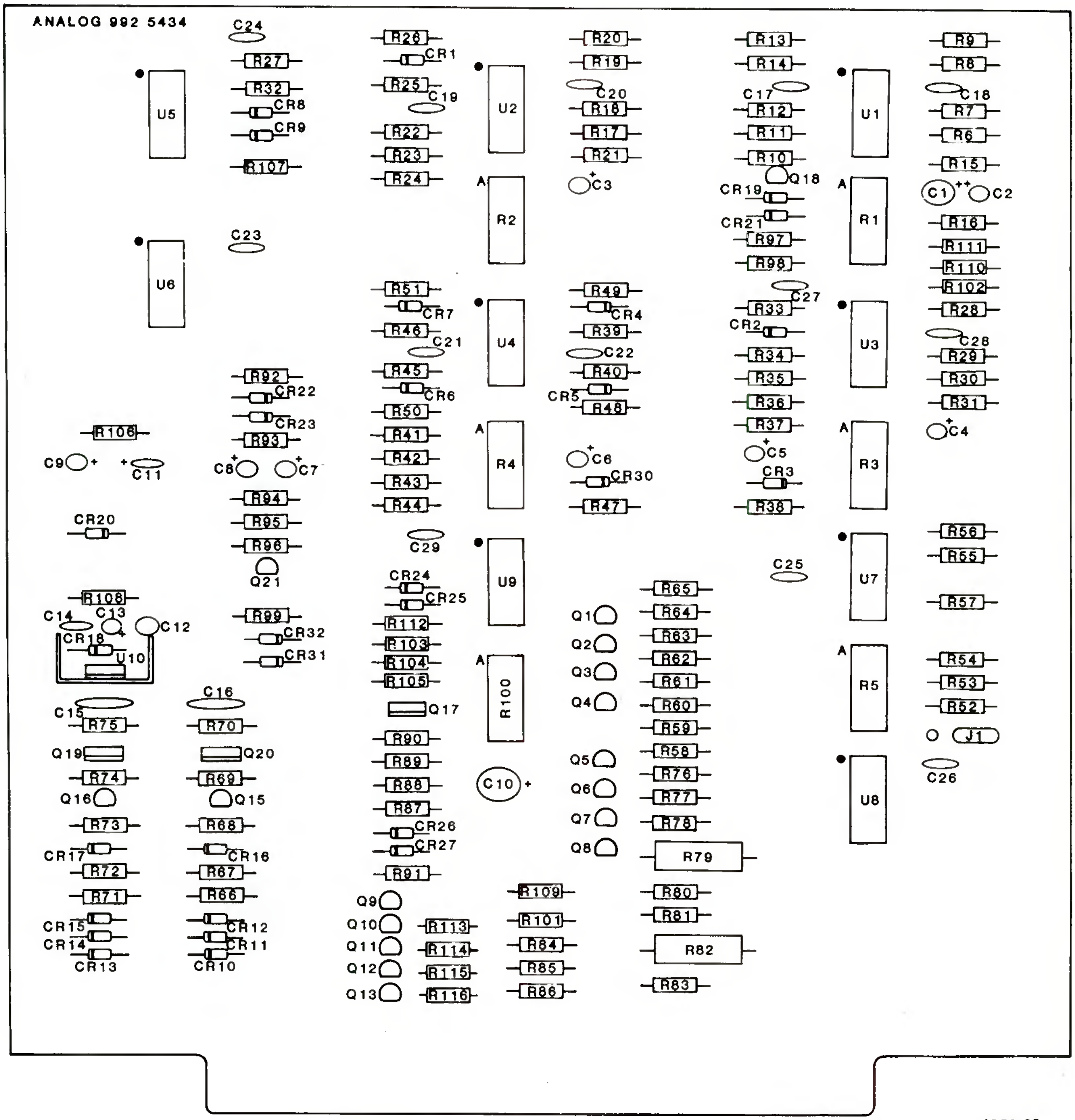
WARNING: Disconnect primary power prior to servicing.

WARNING: Disconnect primary power prior to servicing.



1859-22

Figure 5-9. Status Circuit Board Component Locator



1859-25

Figure 5-10. Analog Circuit Board Component Locator

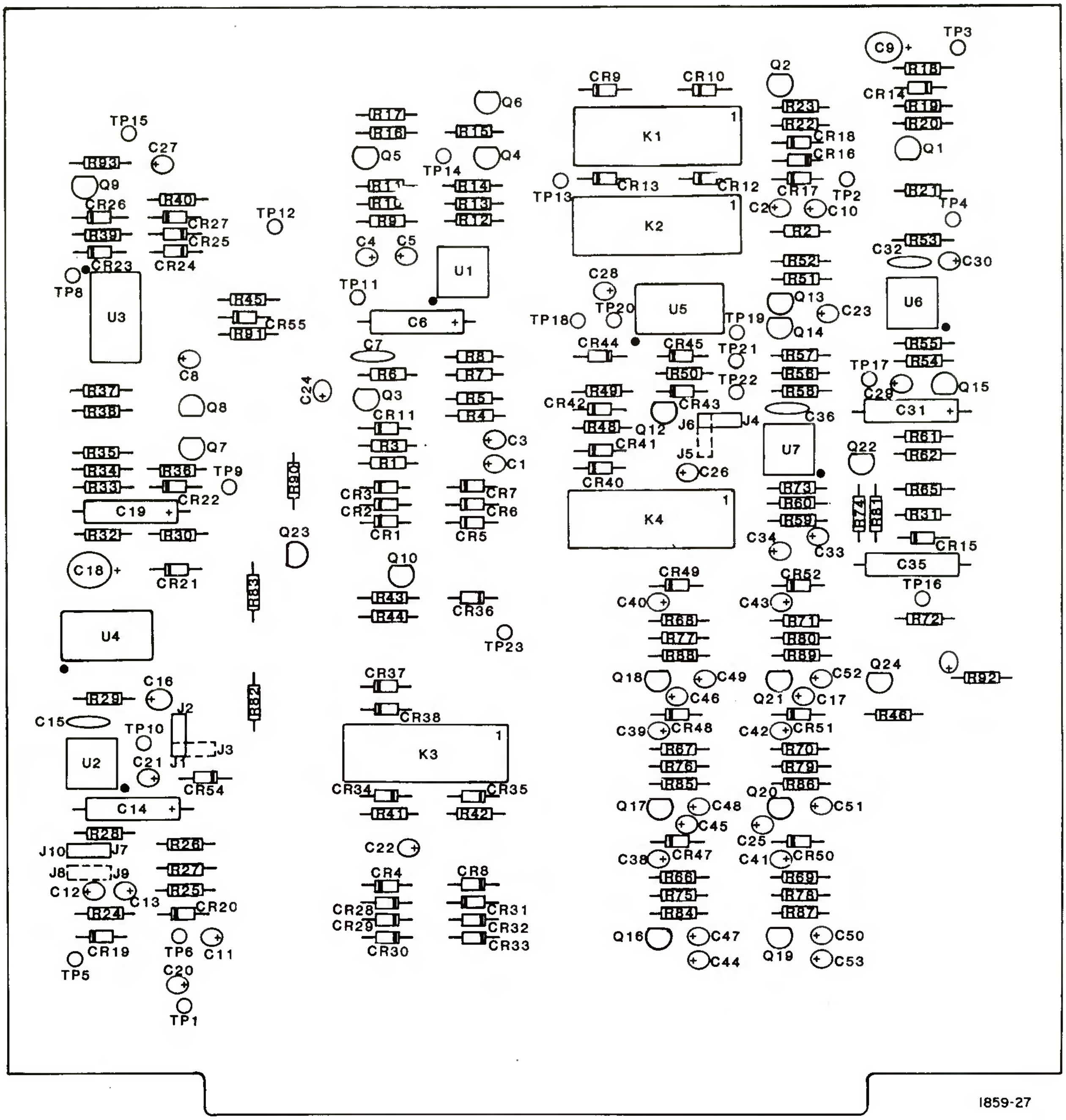
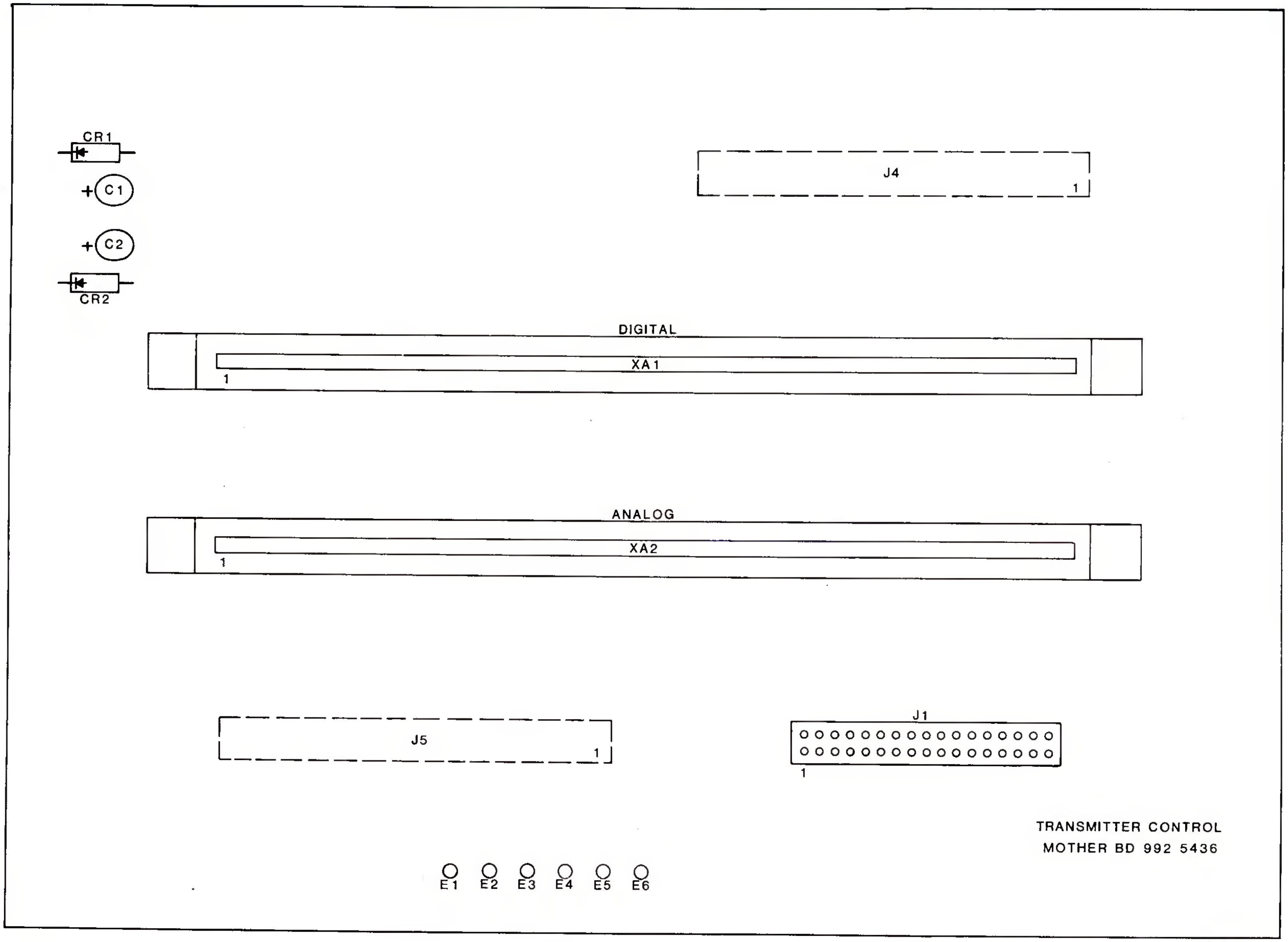


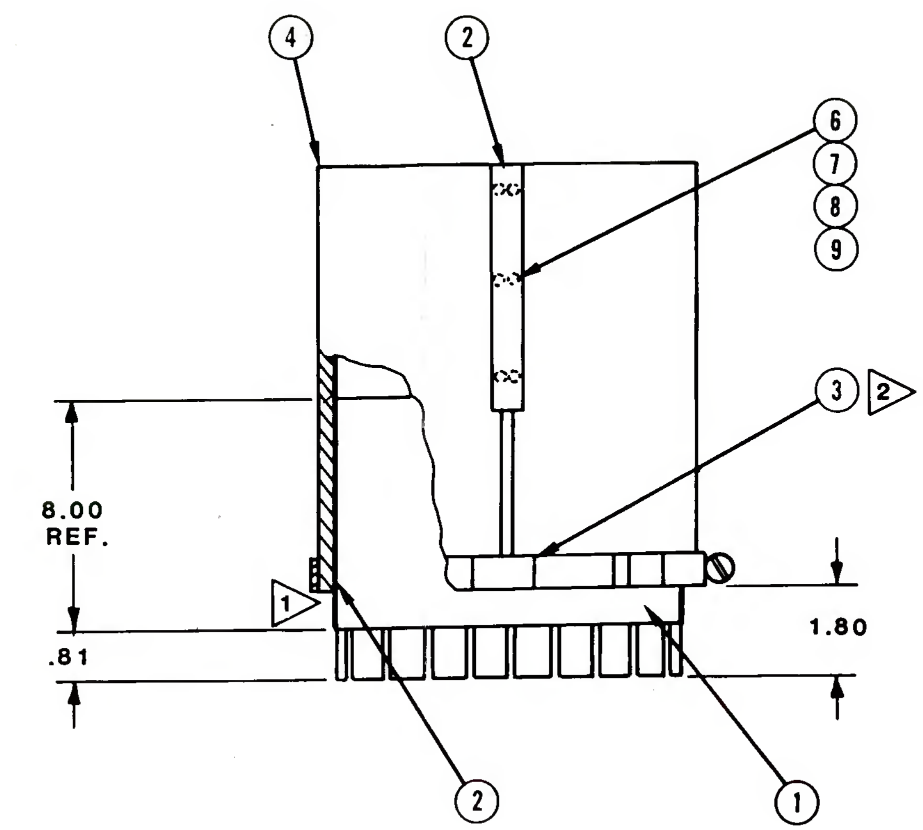
Figure 5-11. Digital Circuit Board Component Locator



1859-44

Figure 5-12. Mother Board Component Locator

ITEM NO.	HARRIS PART NO.	DESCRIPTION	QTY.
1	839 4164 001	Inner Tube	1
2	829 4166 001	Strap, Blocker Shell	1
3	929 7488 001	Clamp Assembly	1
4	829 4165 001	Shell, Outer Anode Blocker	1
5	033 4010 010	Polymide Film, .005 X 8 In.	11Ft.
6	300 1537 000	Screw, 6-32 X 5/16 Pan Head Brass	6
7	308 0005 000	Washer No. 6 Flat, Brass	6
8	312 0047 000	Washer No. 6 Splitlock, Phos. Bronze	6
9	304 0034 000	Nut, Acorn 6-32, Brass	6



3 ASSEMBLY TO BE HI-POTTED TO 15KVDC FOR 2 MIN.

2 CENTER BLOCK ON CLAMP ASSEMBLY TO BE ORIENTED AS SHOWN

1 WRAP ITEM 5 AROUND ITEM 2 5 TURNS

1859-59

1/4 Res color

TQ CLAMP = 358-1036

FIGURE 5-13. PLATE BLOCKER ASSEMBLY

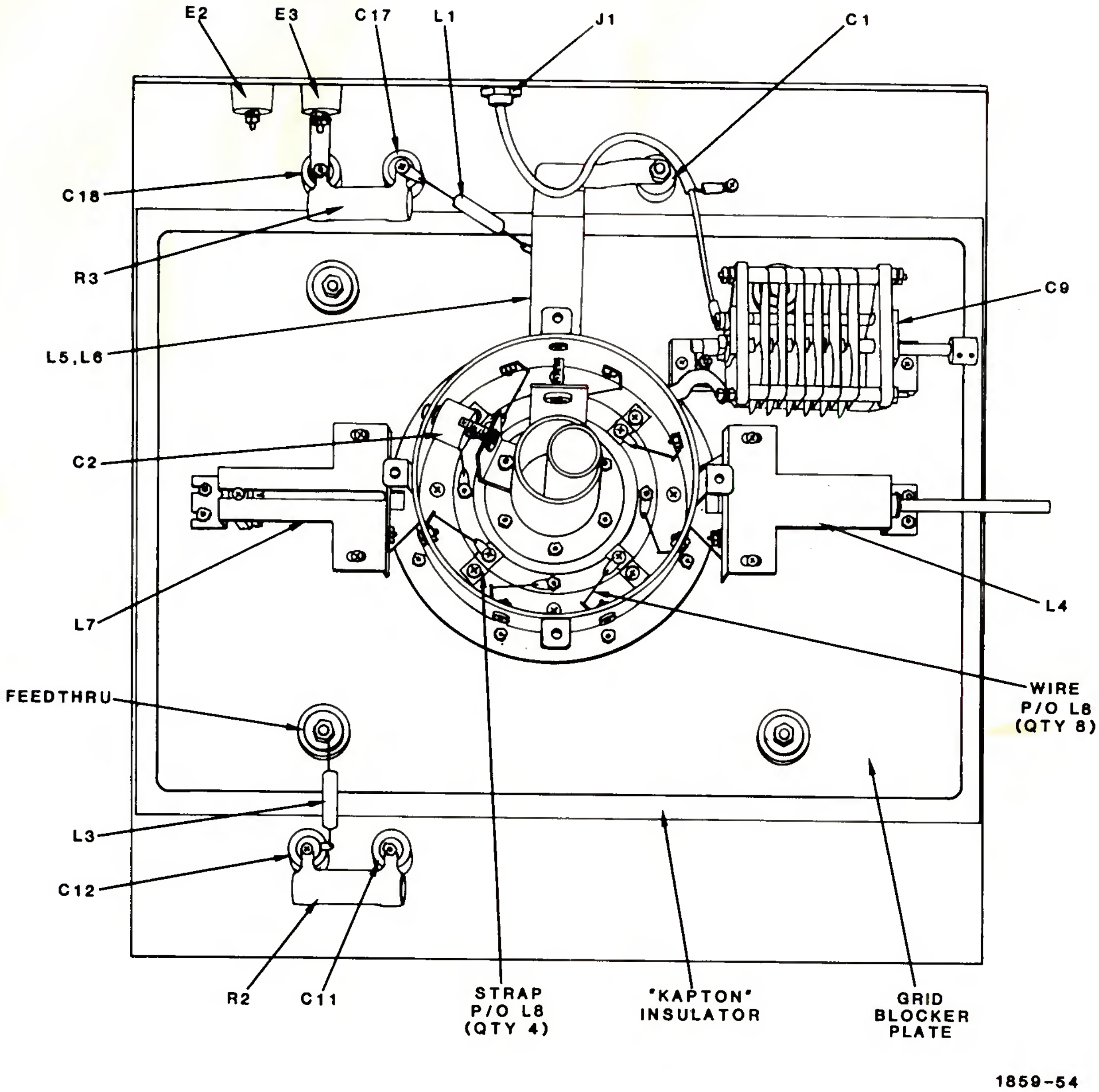


Figure 5-14. Tube Socket Deck, Lower Side

WARNING: Disconnect primary power prior to servicing.

SECTION VI

TROUBLESHOOTING

6-1. INTRODUCTION

6-2. This section provides troubleshooting charts and general troubleshooting information.

6-3. PURPOSE

6-4. The information in this section is intended to aid maintenance personnel in isolating problems in the FM-25K transmitter with minimum down time. The charts serve as an aid to the repairman in locating a particular problem area. Once the problem has been identified refer to Section V for adjustments, component identification, and replacement information.

6-5. TROUBLESHOOTING

6-6. Most troubleshooting consists of visual checks. Because of the voltages and high dc currents in the transmitter, it is not safe to work with power energized. The meters, indicators, and fuses should be used to determine which stage is malfunctioning.

6-7. In event of problems, isolate the trouble area to one of the following with the meters and indicators for each section (see tables 6-1 and 6-2).

a. Antenna and Feedline

b. Power Supplies

c. Control and Metering

d. IPA DRIVER or IPA AMP Module

e. Exciter

f. Power Amplifier

6-8. Once the troulbe is isolated to a specific area, refer to the theory section of this manual for circuit discussion to aid in problem resolution. Table 6-3 lists typical trouble symptoms pertaining to the overall transmitter operation with references to fault isolation diagrams listing probable causes and corrective actions. A corrective action given for a trouble symptom is not necessarily the only answer to a problem, it only tends to lead the repairman to the area that may be causing the trouble.

6-9. TECHNICAL ASSISTANCE

6-10. HARRIS Technical and Troubleshooting assistance are available from HARRIS Field Service Department 24 hours a day. Telephone 217/222-8200 to contact the Field Service Department or address correspondence to Field Service Department, HARRIS CORPORATION, Broadcast Products Division, P.O. Box 4290, Quincy, Illinois 62305-4290, USA. The HARRIS factory may also be contacted through a TWX facility (910-246-3312) or a TELEX service (40-4347). Prior to starting a troubleshooting procedure check all switches, power cord con- nections, connecting cables, and power fuses.

Table 6-1. Typical Operating Parameters*

SWITCH	POSITION	METER	INDICATION
IPA Stage Multi-meter switch	Filament Voltage	IPA Multimeter	9.5 Volts
	Bias Voltage	IPA Multimeter	-310 Volts
	Bias Current	IPA Multimeter	43 mA
	Screen Voltage	IPA Multimeter	870 Volts
	Screen Current	IPA Multimeter	160 mA
IPA Stage REFLECTED POWER/FORWARD Power Switch	Reflected Power	IPA Power Meter	1 Watt
	Forward Power	IPA Power Meter	325 Watts
Transmitter Power Switch	Forward	Power Meter	100% Power (25 kW)
	Reflected	Power Meter	1.09 VSWR
		Plate Voltage	9.25 Kilo Volts
		Plate Current	3.51 Amperes

PA EFFICIENCY - 77.6%

PA PLATE DISSIPATION - 7.2 kW

AC LINE FREQUENCY - 60 Hz

AC LINE VOLTAGE - 235/235/235 Volts

AC LINE CURRENT - 8.5/15/15 and 88/91/89 Amperes

*Always refer to the factory test data sheet sent with the transmitter.

Table 6-2. Meter Indications with Varying Power Levels

TRANSMITTER PARAMETER	POWER 1	POWER 2	POWER 3
Power Output	10.17 kW	15.57 kW	20.2 kW
Plate Voltage	9.45 kV	9.4 kV	9.4 kV
Plate Current	1.47 A	2.1 A	2.7 A
Screen Voltage	920 V	910 V	900 V
Screen Current	95 mA	135 mA	145 mA
Grid Voltage	439 V	430 V	438 V
Grid Current	(-)	(-)	4 mA
IPA Voltage	22.7 V	25.1 V	27 V
PA Efficiency	73.2 %	78.8 %	79.5 %
PA Plate Dissipation	3.7 kW	4.17 kW	5.18 kW

Table 6-3. Symptom Index

SYMPTOM	DEFECT/REFERENCE
TRANSMITTER RF OUTPUT POWER SUDDENLY REDUCED TO 90%	One amplifier stage of an IPA AMP module defective.
TRANSMITTER RF OUTPUT POWER SUDDENLY REDUCED TO 80%	2 amplifier stages of an IPA AMP modules defective (one module).
TRANSMITTER RF OUTPUT POWER SUDDENLY REDUCED TO 25%	One amplifier stage of the IPA DRIVER module defective.
NO TRANSMITTER RF OUTPUT POWER	Refer to figure 6-1
LOW RF OUTPUT	Refer to figure 6-2
NO IPA STAGE RF OUTPUT POWER	Refer to figure 6-3
NO OUTPUT INDICATION FROM ONE IPA MODULE OR ONE AMPLIFIER STAGE	Refer to figure 6-4
IPA DRIVER MODULE RFA/RFB INDICATORS ILLUMINATED - IPA AMP MODULE RFA/ RFB INDICATORS OUT	Refer to figure 6-5
RANDOM IPA AMP STAGE RFA AND/OR RFB INDICATORS OUT	Refer to figure 6-6
ALL IPA AMP RFA INDICATORS ILLUMINATED, ALL RFB INDICATORS OUT OR ALL IPA AMP RFB INDICATORS ILLUMINATED, ALL RFB INDICATORS OUT	Refer to figure 6-7
CONTROL CIRCUIT INOPERATIVE	
FILAMENT ON SEQUENCE	Refer to figure 6-8.
FILAMENT OFF SEQUENCE	Refer to figure 6-9.
PLATE ON SEQUENCE	Refer to figure 6-10 (2 sheets).
PLATE OFF SEQUENCE	Refer to figure 6-11.

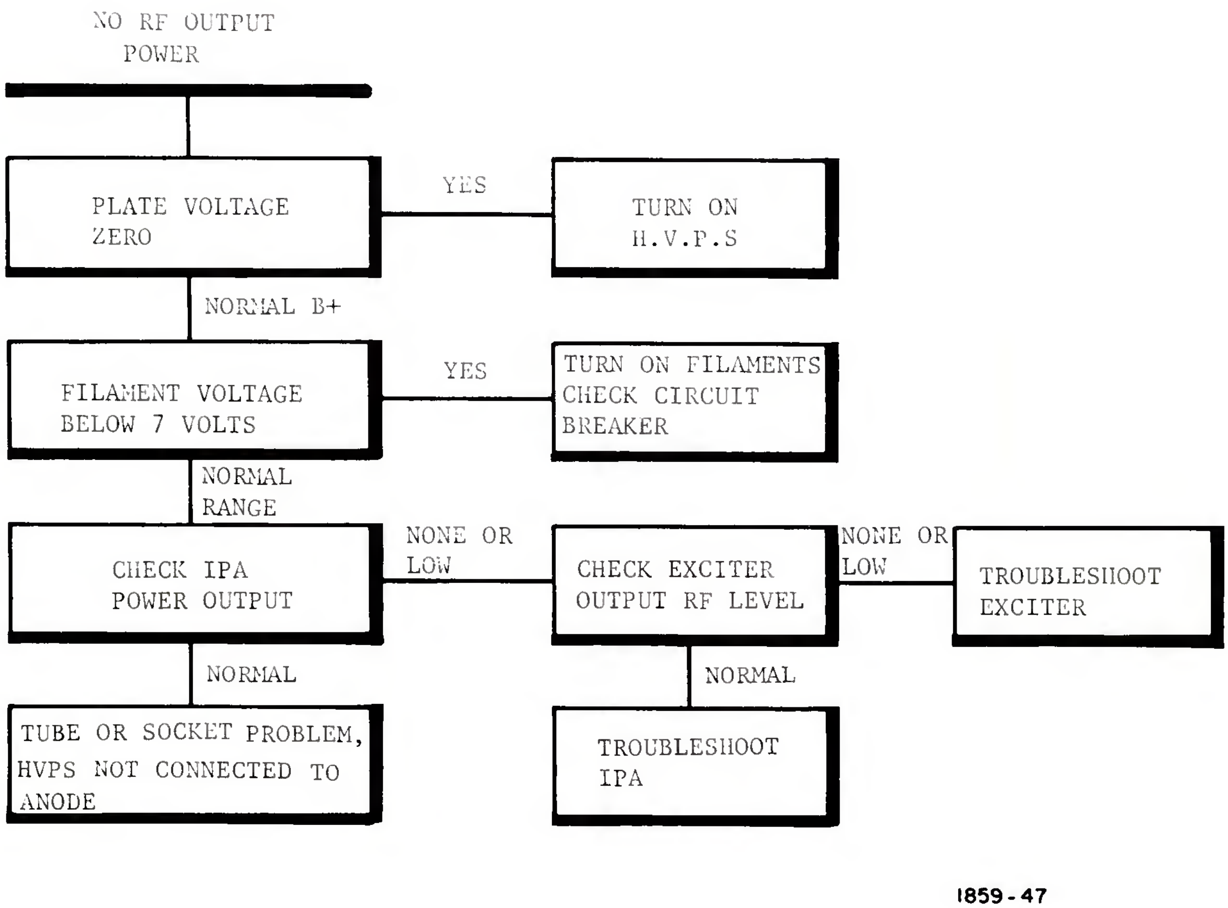


Figure 6-1. No Transmitter RF Output Power

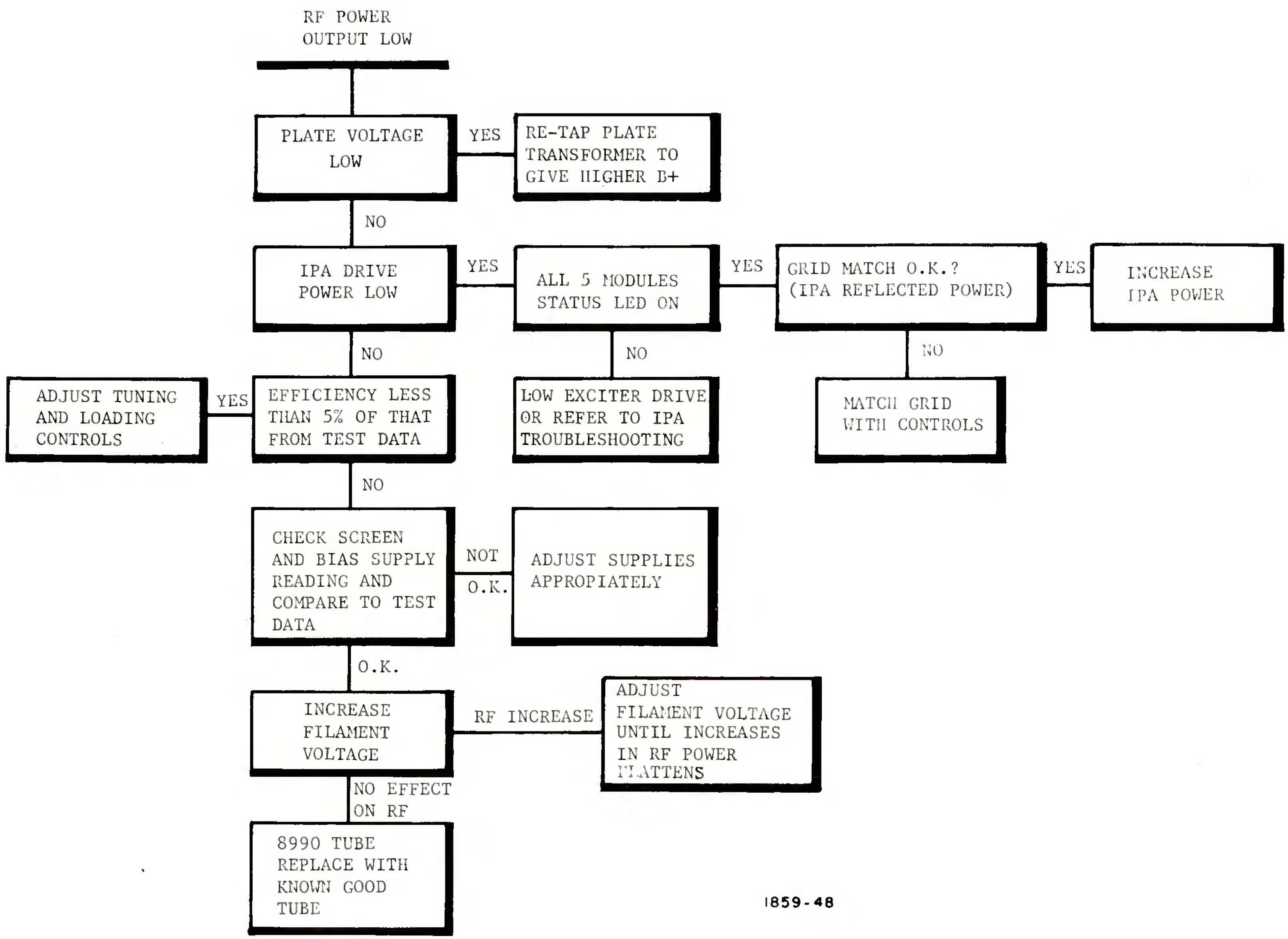


Figure 6-2. Low Transmitter RF Output Power

WARNING: Disconnect primary power prior to servicing.

888-1859-001

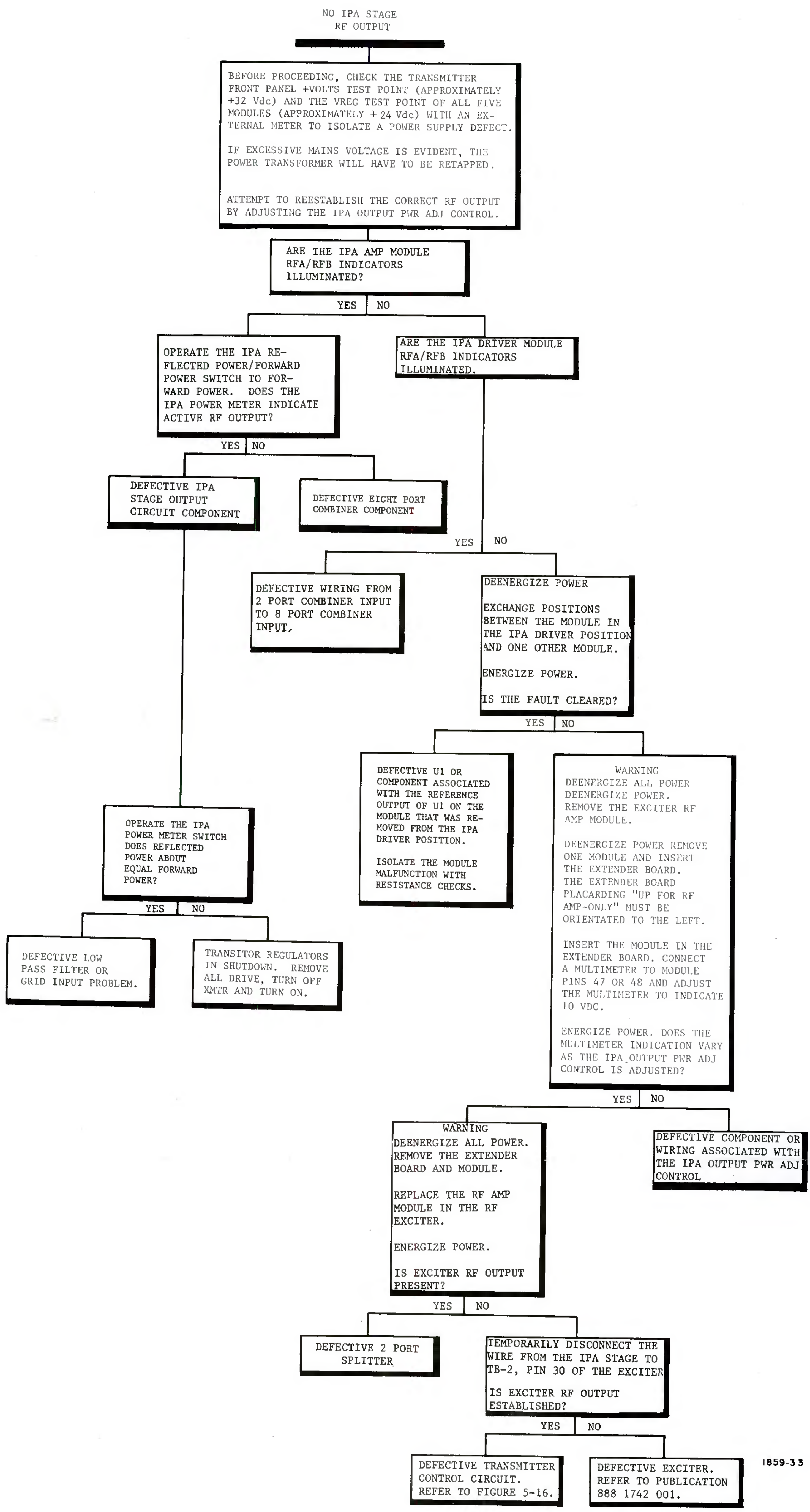


FIGURE 6-3. NO IPA STAGE RF OUTPUT POWER

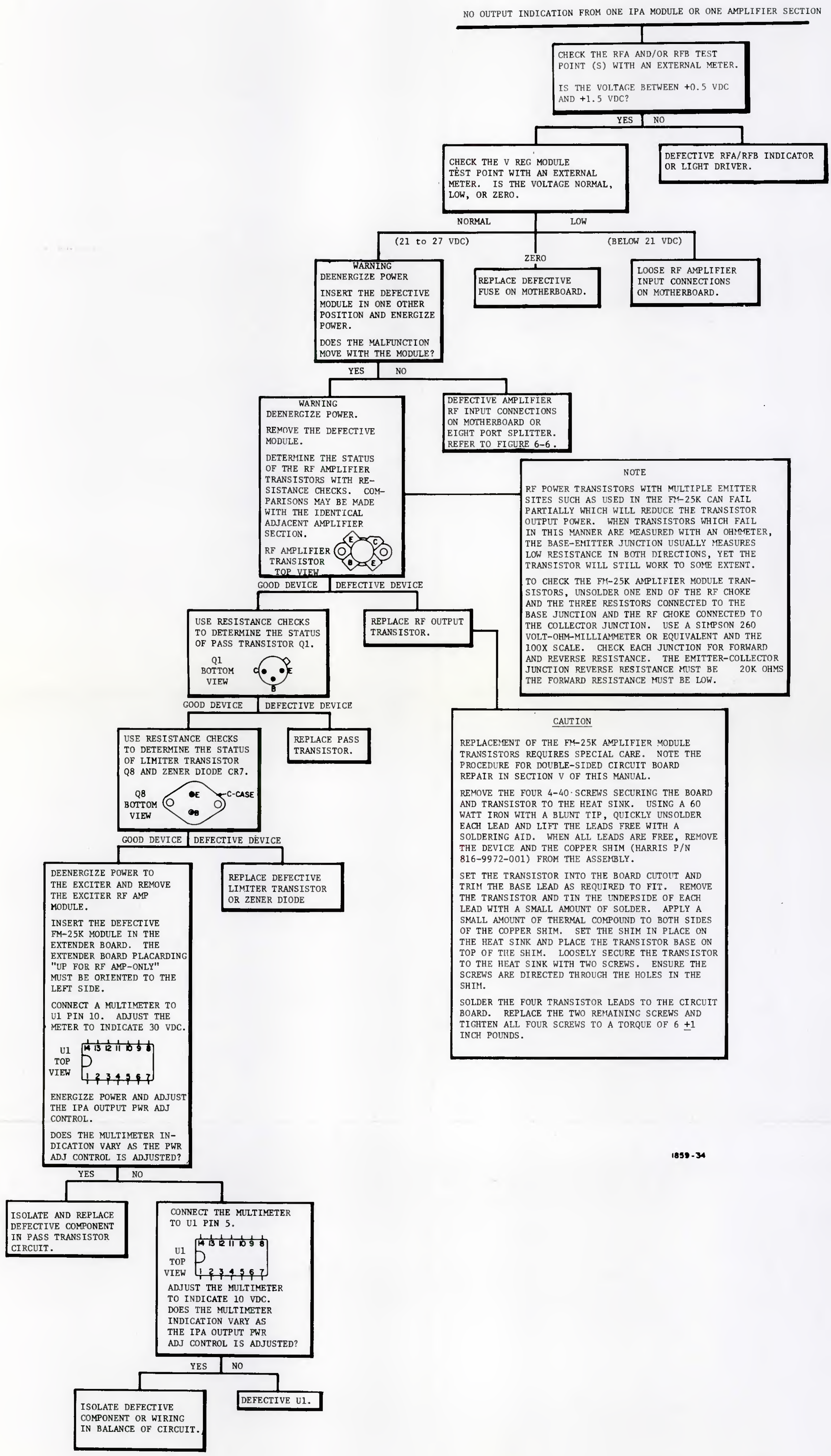


FIGURE 6-4. NO OUTPUT INDICATION FROM ONE IPA MODULE OR ONE AMPLIFIER SECTION

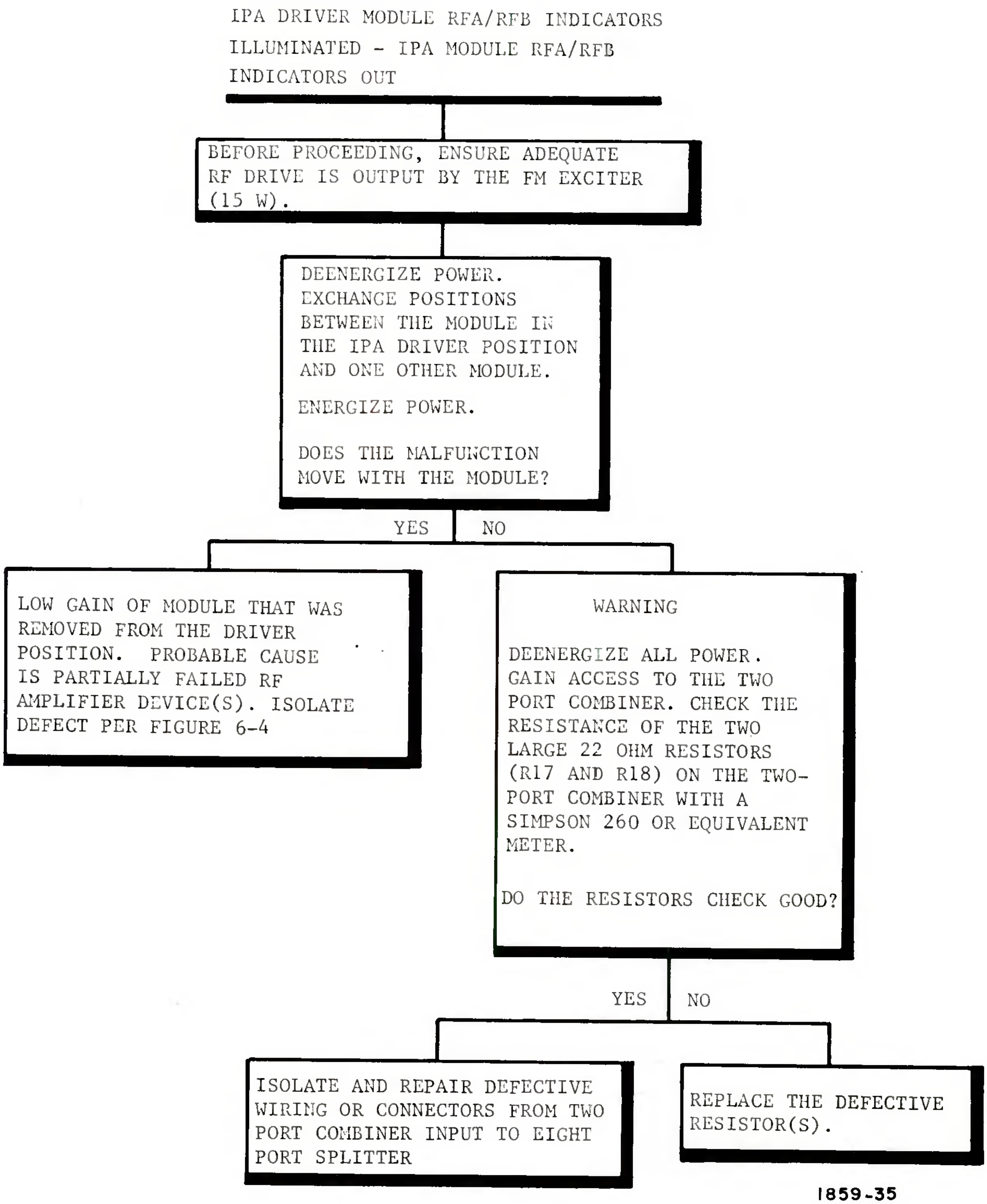


Figure 6-5. IPA Driver Module RFA/RFB Indicators Illuminated - PA Module RFA/RFB Indicators Out

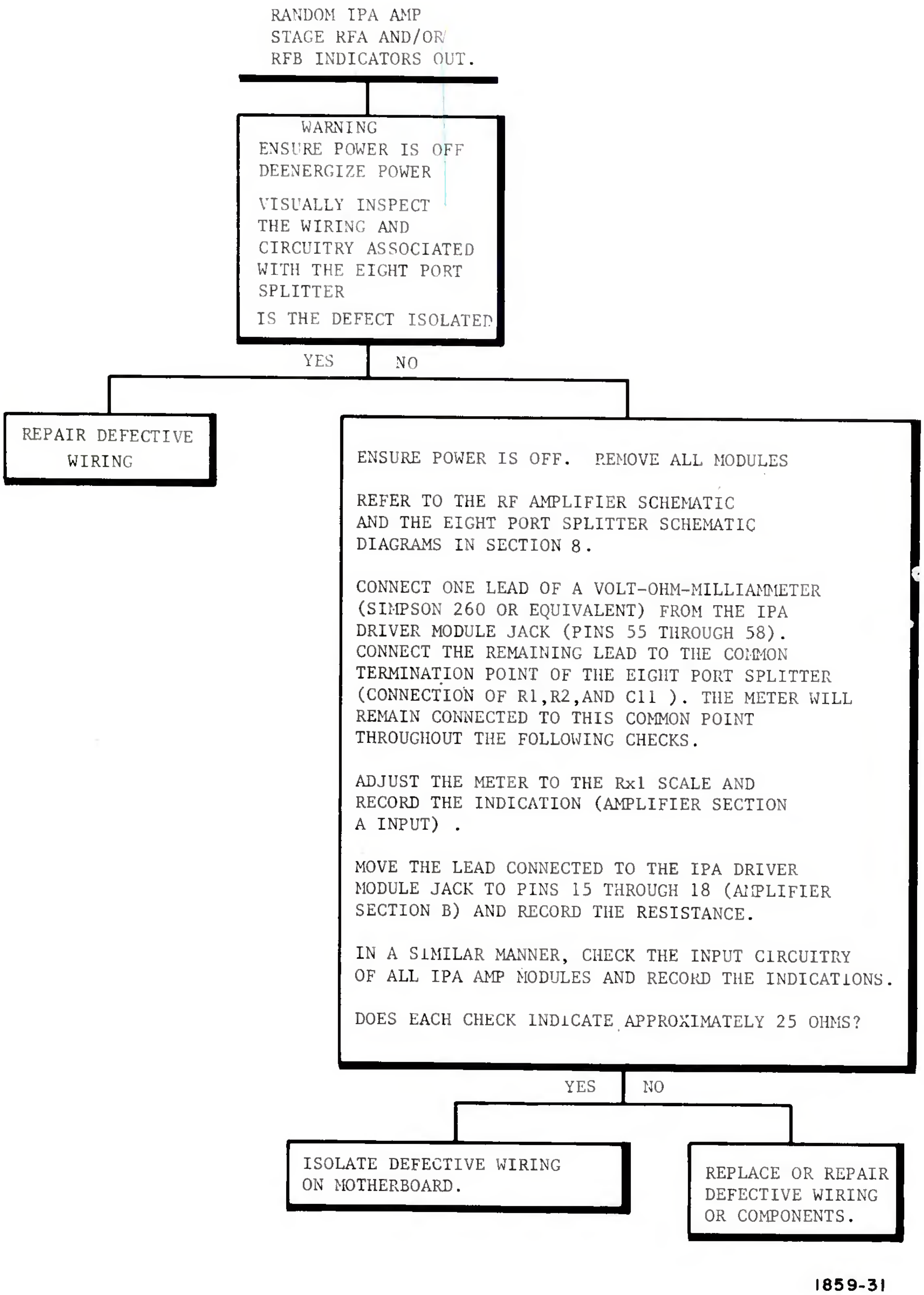


Figure 6-6. Random IPA Amp Stage RFA and/or RFB Indicators Out

ALL IPA AMP INDICATORS OUT/RFB INDICATORS ON OR ALL IPA AMP RFB INDICATORS OUT/RFA INDICATORS ON

IS THE CORRESPONDING IPA DRIVER MODULE RFA/RFB INDICATOR OUT ?

YES

DEFECTIVE TWO PORT SPLITTER.

WARNING
ENSURE POWER IS OFF
DEENERGIZE ALL POWER

REMOVE THE IPA DRIVER MODULE, OR UNPLUG THE EXCITER RF OUTPUT CABLE

ISOLATE THE DEFECTIVE CIRCUITRY WITH CONTINUITY OR RESISTANCE CHECKS PER THE RF AMPLIFIER MODULE SCHEMATIC DIAGRAM AND THE COMBINER/SPLITTER SCHEMATIC DIAGRAMS IN SECTION 8.

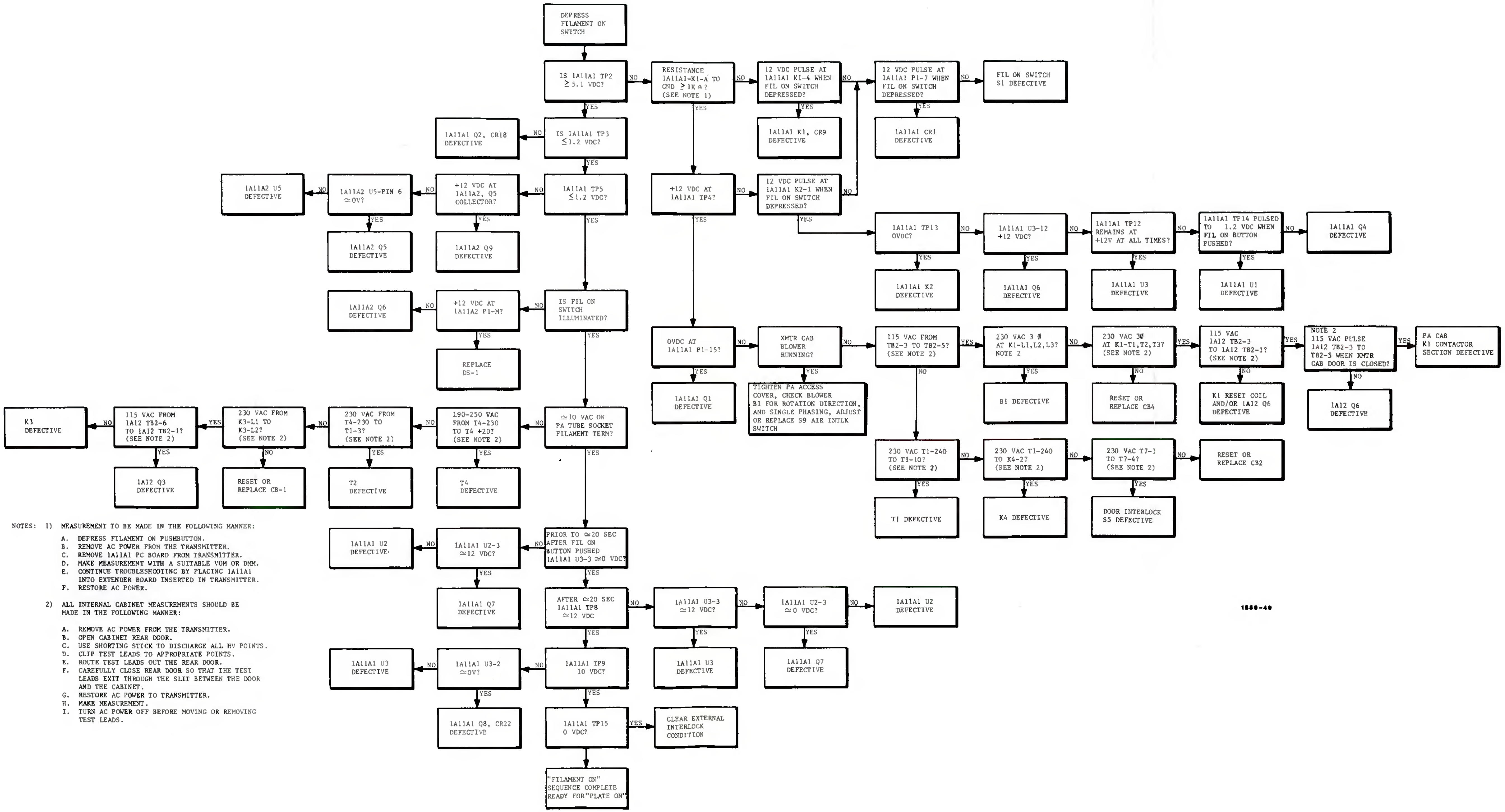
NO

DEFECTIVE TWO PORT COMBINER.
WARNING
ENSURE POWER IS OFF
DEENERGIZE ALL POWER.

REMOVE THE IPA DRIVER MODULE. ISOLATE THE DEFECTIVE CIRCUITRY WITH CONTINUITY OR RESISTANCE CHECKS PER THE COMBINER/SPLITTER SCHEMATIC DIAGRAM IN SECTION 8.

1859-32

Figure 6-7. All IPA Amp RFA Indicators Illuminated, RFB Indicators Out of All IPA Amp RFB Indicators Illuminated, RFA Indicators Out



NOTES: 1) MEASUREMENT TO BE MADE IN THE FOLLOWING MANNER:

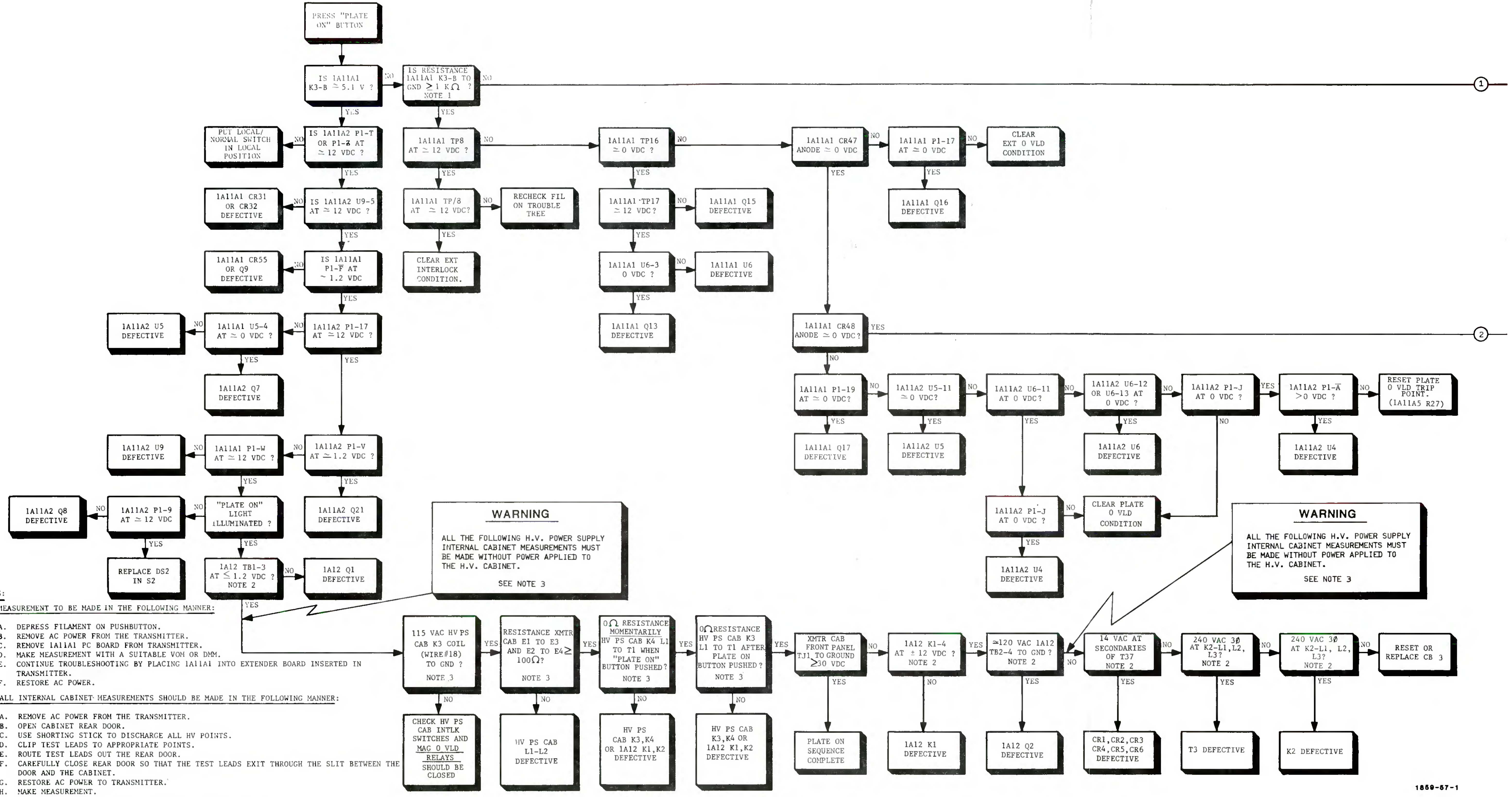
A. DEPRESS FILAMENT ON PUSHBUTTON.
B. REMOVE AC POWER FROM THE TRANSMITTER.
C. REMOVE 1A11A1 PC BOARD FROM TRANSMITTER.
D. MAKE MEASUREMENT WITH A SUITABLE VOM OR DMM.
E. CONTINUE TROUBLESHOOTING BY PLACING 1A11A1 INTO EXTENDER BOARD INSERTED IN TRANSMITTER.
F. RESTORE AC POWER.

2) ALL INTERNAL CABINET MEASUREMENTS SHOULD BE MADE IN THE FOLLOWING MANNER:

A. REMOVE AC POWER FROM THE TRANSMITTER.
B. OPEN CABINET REAR DOOR.
C. USE SHORTING STICK TO DISCHARGE ALL HV POINTS.
D. CLIP TEST LEADS TO APPROPRIATE POINTS.
E. ROUTE TEST LEADS OUT THE REAR DOOR.
F. CAREFULLY CLOSE REAR DOOR SO THAT THE TEST LEADS EXIT THROUGH THE SLIT BETWEEN THE DOOR AND THE CABINET.
G. RESTORE AC POWER TO TRANSMITTER.
H. MAKE MEASUREMENT.
I. TURN AC POWER OFF BEFORE MOVING OR REMOVING TEST LEADS.

FIGURE 6-8. CONTROL CIRCUIT INOPERATIVE (FILAMENT ON SEQUENCE)

FIGURE 6-9. CONTROL CIRCUIT INOPERATIVE (FILAMENT OFF SEQUENCE)



NOTES:

1) MEASUREMENT TO BE MADE IN THE FOLLOWING MANNER:

A. DEPRESS FILAMENT ON PUSHBUTTON.
B. REMOVE AC POWER FROM THE TRANSMITTER.
C. REMOVE 1A11A1 PC BOARD FROM TRANSMITTER.
D. MAKE MEASUREMENT WITH A SUITABLE VOM OR DMM.
E. CONTINUE TROUBLESHOOTING BY PLACING 1A11A1 INTO EXTENDER BOARD INSERTED IN TRANSMITTER.
F. RESTORE AC POWER.

2) ALL INTERNAL CABINET MEASUREMENTS SHOULD BE MADE IN THE FOLLOWING MANNER:

A. REMOVE AC POWER FROM THE TRANSMITTER.
B. OPEN CABINET REAR DOOR.
C. USE SHORTING STICK TO DISCHARGE ALL HV POINTS.
D. CLIP TEST LEADS TO APPROPRIATE POINTS.
E. ROUTE TEST LEADS OUT THE REAR DOOR.
F. CAREFULLY CLOSE REAR DOOR SO THAT THE TEST LEADS EXIT THROUGH THE SLIT BETWEEN THE DOOR AND THE CABINET.
G. RESTORE AC POWER TO TRANSMITTER.
H. MAKE MEASUREMENT.
I. TURN AC POWER OFF BEFORE MOVING OR REMOVING TEST LEADS.

3) ALL INTERNAL HIGH VOLTAGE POWER SUPPLY CABINET MEASUREMENTS SHOULD BE MADE IN THE FOLLOWING MANNER:

A. REMOVE AC POWER FROM THE HIGH VOLTAGE CABINET AND THE TRANSMITTER.
B. REMOVE THE APPROPRIATE COVER ASSEMBLY FROM THE HIGH VOLTAGE POWER SUPPLY.
C. USE SHORTING STICK TO DISCHARGE ALL HV POINTS.
D. CLIP TEST LEADS TO APPROPRIATE POINTS.
E. ROUTE TEST LEADS OUT OF COVER OPENING.
F. CAREFULLY REPLACE THE COVER SO THAT THE TEST LEADS EXIT THROUGH THE SLIT BETWEEN THE COVER AND THE CABINET.
G. RESTORE AC POWER TO THE TRANSMITTER BUT NOT TO THE HIGH VOLTAGE POWER SUPPLY.
H. MAKE MEASUREMENT.
I. TURN AC POWER OFF BEFORE MOVING OR REMOVING TEST LEADS.

FIGURE 6-10. CONTROL CIRCUIT INOPERATIVE (PLATE ON SEQUENCE)

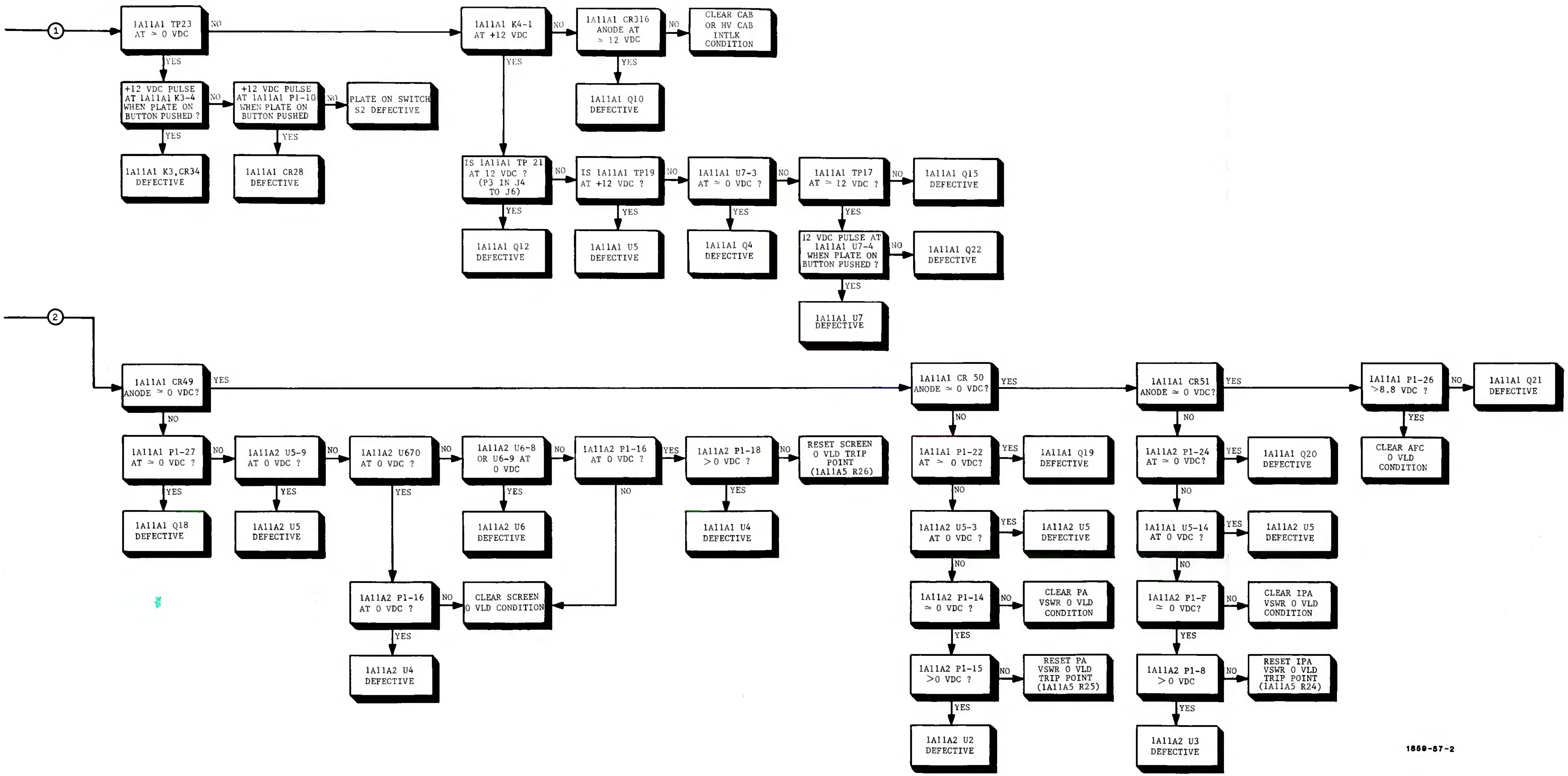


FIGURE 6-10. CONTROL CIRCUIT INOPERATIVE (PLATE ON SEQUENCE)

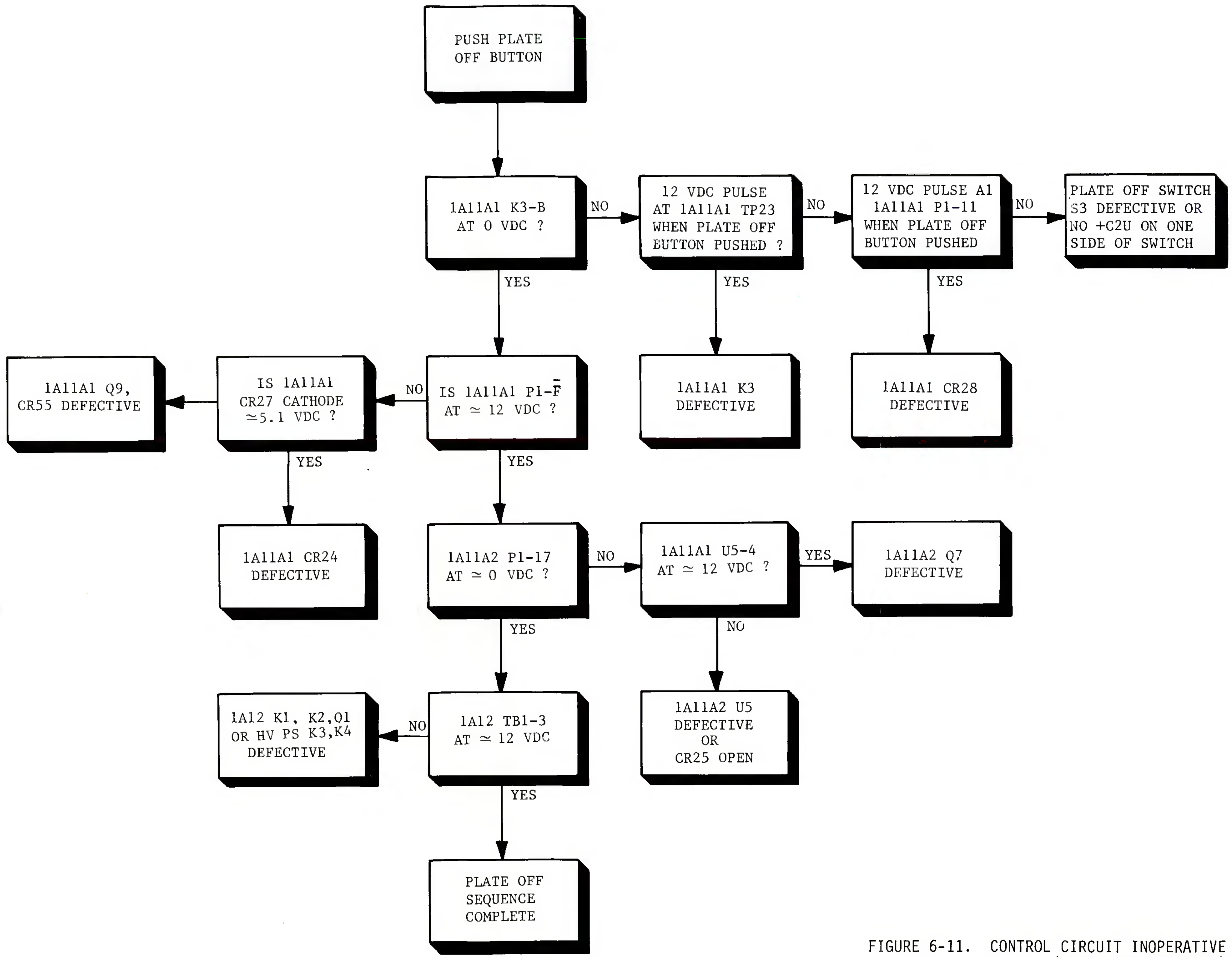


FIGURE 6-11. CONTROL CIRCUIT INOPERATIVE (PLATE OFF SEQUENCE)

SECTION VII

PARTS LIST

7-1. INTRODUCTION

7-2. This section provides a description, reference designator, and order number for replaceable electrical parts, assemblies, and selected mechanical parts necessary for proper maintenance of the FM-25K Transmitter. Table 7-1 is the replaceable parts list index for all assemblies and subassemblies in the transmitter.

7-3. REPLACEABLE PARTS SERVICE

7-4. Replacement parts are available 24 hours a day, seven days a week from the HARRIS Service Parts Department. Telephone 217/222-8200 to contact the service parts department or address correspondence to Service Parts Department, HARRIS Broadcast Products Division, HARRIS CORPORATION, P.O. Box 4290, Quincy, Illinois 62305-4290, USA. The HARRIS factory may also be contacted through a TWX facility (910-246-3312) or a TELEX service (40-4347).

Table 7-1. Replaceable Parts List Index

TABLE NO.	UNIT NOMENCLATURE	PART NO.	PAGE
7-2	FM-25K Transmitter	994 8258 001	7-4
7-3	Basic FM-25K Transmitter	994 8258 002	7-5
7-4	Power Amplifier Assembly	992 5427 001	7-6
7-5	IPA Module Assembly	992 5352 001	7-7
7-6	Dual RF Amplifier PC Board	992 5353 001	7-8
7-7	8 Port Combiner Assembly	992 5440 001	7-11
7-8	8 Port Resistor Board	992 5493 001	7-12
7-9	8 Port Output Board	992 5492 001	7-13
7-10	PA Cavity Assembly	992 5431 001	7-14
7-11	Socket/Input Circuit Assembly	992 5567 001	7-15
7-12	Transmitter Control	992 5432 001	7-16
7-13	Digital Logic PC Board Assembly	992 5433 001	7-17
7-14	Analog PC Board Assembly	992 5434 001	7-23
7-15	RFI PC Board Assembly	992 5435 001	7-30
7-16	Mother Board Assembly	992 5436 001	7-32
7-17	Status PC Board Assembly	992 5437 001	7-33
7-18	Ribbon RFI Cable	929 7186 001	7-34
7-19	Ribbon Display Cable	929 7187 001	7-35
7-20	Low Pass Filter/Directional Coupler Assembly	992 5620 001	7-36
7-21	Cabinet Assembly	992 5438 001	7-37
7-22	AC Control PC Assembly	992 5439 001	7-41
7-23	Resistor Assembly	917 0570 001	7-44

WARNING: Disconnect primary power prior to servicing.

Table 7-1. Replaceable Parts List Index (Continued)

TABLE NO.	UNIT NOMENCLATURE	PART NO.	PAGE
7-24	IPA Frame Assembly	992 5351 001	7-45
7-25	Combiner/Splitter Assembly	992 5349 001	7-46
7-26	Mother Board Assembly	992 5350 001	7-47
7-27	HV Power Supply	992 5428 001	7-48
7-28	Resistor/Diode Assembly	929 7733 001	7-50
7-29	HV Shorting Assembly	992 5480 001	7-51
7-30	Extender Card for Controller	992 5646 001	7-52

WARNING: Disconnect primary power prior to servicing.

Table 7-2. FM-25K Transmitter - 994 8258 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
1A1	994 7950 001	FM Exciter	1
B1	436 0212 000	Motor, 230/460V, 60 Hz, 3 PH, 2HP (For 216V to 250V Line)	--
B1 (Alternate)	436 0215 000	Motor, 200V, 60 Hz, 3 PH, 2 HP (For 190V to 215V Line)	--
B1	436 0216 000	Motor, 220/380V, 50 Hz, 3 PH, 2 HP (For 198V to 242V)	--
M1 (Alternate)	636 0038 000	Meter, Elapsed Time, 50 Hz, 230V	--
V1	374 0151 000	Vacuum Tube, Eimac 8990	1
Unit 2	994 6172 001	Low-Pass Filter 88-92, 98-108 MHz	--
Unit 2 (Alternate)	994 6172 002	Low Pass Filter 92-98 MHz	--
	994 9258 002	Basic FM-25K Transmitter	1
		For 360-415 Volt Service Only the following parts are required	
	510 0574 000	Capacitor, 30 uF, 370 Vac	3

WARNING: Disconnect primary power prior to servicing.

Table 7-3. Basic FM-25K Transmitter - 994 8258 002

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
DC2	620 1595 000	Coupler, Directional, 20 kW	1
Unit 1	992 5427 001	Power Amplifier Assembly	1
Unit 3	992 5428 001	High Voltage Power Supply	1
	992 5646 001	Extender Board for Controller	1
	612 0942 000	Housing, Socket, 24 Pin (For Remote Control)	2
	354 0627 000	Contact, Socket, (For Remote Control Receptacles)	50

Table 7-4. Power Amplifier Assembly - 992 5427 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
A2,A3,A4,A5,A6	992 5352 001	IPA Module Assembly	5
A9	992 5440 001	8 Port Combiner Assembly	1
A10	992 5431 001	PA Cavity Assembly	1
A11	992 5432 001	Transmitter Control	1
A13	992 5620 001	Directional Coupler Assembly	1
M1	636 0039 000	Meter, Elapsed Time, 60 Hz, 230V	1
	992 5438 001	Cabinet Assembly	1
	992 5351 001	IPA Frame Assembly	1
	929 7813 001	Cable, MS-15 RF Output to IPA 2 Port Combiner	1
	929 7814 001	Cable, Coax, DC1, J2 to PA Cavity	1
	929 7815 001	Cable, DC1, J1 to 8 Port Combiner	1

WARNING: Disconnect primary power prior to servicing.

Table 7-5. IPA Module Assembly - 992 5352 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
Q1	380 0588 000	Transistor, 2N6282	1
Q2,Q3	380 0600 000	Transistor, CD2315	2
R42	540 0308 000	Resistor, 100 ohms, 1W, 5%	1
T1	929 4964 001	Transformer Assembly	1
T2	929 4964 001	Transformer Assembly	1
T3	929 4964 002	Transformer Assembly	1
T4	929 4964 001	Transformer Assembly	1
XQ1	404 0661 000	Socket, Transistor, TO-3	1
	992 5353 001	Dual RF Amplifier PC Board	1

WARNING: Disconnect primary power prior to servicing.

Table 7-6. Dual RF Amplifier PC Board - 992 5353 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2	508 0378 000	Capacitor, .22 uF, 100V	2
C3,C4	516 0080 000	Capacitor, .01 uF, 600V	2
C5	516 0375 000	Capacitor, .01 uF, 50V	1
C6,C7,C8	516 0080 000	Capacitor, .01 uF, 600V	3
C9,C10,C11,C12	516 0375 000	Capacitor, .01 uF, 50V	4
C13,C14	500 1229 000	Capacitor, 22 pF, 350V	2
C15,C16	500 1234 000	Capacitor, 150 pF, 350V	2
C17,C18	526 0349 000	Capacitor, 2.2 uF, 50V	2
C19,C20,C21,C22	500 1237 000	Capacitor, 1000 pF, 500V	4
C23,C24,C25,C26	500 1235 000	Capacitor, 270 pF, 350V	4
C27,C28	500 1237 000	Capacitor, 1000 pF, 500V	2
C29,C30	500 1239 000	Capacitor, 27 pF, 350V	2
C31,C32	500 1235 000	Capacitor, 270 pF, 350V	2
C33,C34	500 0801 000	Capacitor, 2 pF, 500V	2
C35	516 0375 000	Capacitor, .01 uF, 50V	1
C36	526 0310 000	Capacitor, .22 uF, 35V	1
C37,C38,C39,C40	500 0833 000	Capacitor, 390 pF, 500V	4
CR1,CR2,CR3,CR4	386 0399 000	Diode, Zener, 1N5231B	4
CR7	386 0403 000	Diode, Zener, 1N5257B	1
DS1,DS2	384 0661 000	LED. Green	2
L1,L2	494 0219 000	Inductor, 250 MHz	2

WARNING: Disconnect primary power prior to servicing.

Table 7-6. Dual RF Amplifier PC Board - 992 5353 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
L3,L4	494 0218 000	Inductor, 180 MHz	2
Q4,Q5,Q6,Q7	380 0189 000	Transistor, 2N3904	4
Q8	380 0195 000	Transistor, 2N4239	1
R1,R2	548 1487 000	Resistor, .1 ohm, 10W, 1%	2
R3	540 1190 000	Resistor, 240 ohm, 1/2W, 5%	1
R4	540 1154 000	Resistor, 7.5k ohm, 1/2W, 5%	1
R5	548 1430 000	Resistor, 23.2k ohm, 1/4W, 1%	1
R7	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R8	548 0279 000	Resistor, 2k ohm, 1/4W, 1%	1
R9	548 0869 000	Resistor, 604 ohm, 1/4W, 1%	1
R10	548 0866 000	Resistor, 56.2k ohm, 1/4W, 1%	1
R11	548 0283 000	Resistor, 12.7k ohm, 1/4W, 1%	1
R12	540 0613 000	Resistor, 1.2k ohm, 2W, 5%	1
R13	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R14	548 0279 000	Resistor, 2k ohm, 1/4W, 1%	1
R15	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R16,R17	540 1102 000	Resistor, 100 ohm, 1/2W, 5%	2
R18,R19	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R20,R21	540 1102 000	Resistor, 100 ohm, 1/2W, 5%	2
R22,R23	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	2
R24,R25	540 1117 000	Resistor, 150 ohm, 1/2W, 5%	2

WARNING: Disconnect primary power prior to servicing.

Table 7-6. Dual RF Amplifier PC Board - 992 5353 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R26,R27	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	2
R28,R29,R30,R31	540 0593 000	Resistor, 180 ohm, 2W, 5%	4
R32,R33	540 1149 000	Resistor, 3.9 ohm, 1/2W, 5%	2
R34,R35,R36,R37, R38,R39	540 1136 000	Resistor, 56 ohm, 1/2W, 5%	6
R40	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	1
R41	540 1151 000	Resistor, 10 ohm, 1/2W, 5%	1
R44,R45	540 0870 000	Resistor, 18 ohm, 1/4W, 5%	2
TP1,TP2,TP3,TP4	610 0750 000	Test Probe, Type C	4
TP5	612 0890 000	Test Point, Vertical Mount	1
U1	382 0379 000	Integrated Circuit, LM723CD	1
XU1	404 0674 000	Socket, Integrated Circuit, 14 Pin	1
	404 0198 000	Transipad for Q8	1
	939 4792 001	Printed Board	1

Table 7-7. 8 Port Combiner Assembly - 992 5440 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
J9	612 0233 000	Receptacle, 'N' UG 58 A/U	1
R1,R2,R3,R4,R5, R6,R7,R8	540 1341 000	Resistor, 22 ohm, 30W, 10%	8
T1,T2,T3,T4,T5 T6,T7,T8	929 4971 001	Cable Interconnector, 8 Port	8
T9,T10	929 4965 001	Cable, Transformer, 8 Port	2
	992 5493 001	8 Port Combiner Resistor Board	1
	992 5492 001	8 Port Combiner Output Board	1
	929 7005 001	PC Board	1

Table 7-8. 8 Port Combiner Resistor Board - 992 5493 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C11,C12,C13,C14, C15,C16,C17,C18	500 1231 000	Capacitor, 47 pF, 350V	8
	929 7006 001	PC Board	1

Table 7-9 8 Port Combiner Output PC Board - 992 5492 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2,C3,C4,C5 C6,C7,C8	500 0805 000	Capacitor, 12 pF, 500V	8
C9	500 1234 000	Capacitor, 150 pF, 350V	1
J1,J2,J3,J4,J5, J6,J7,J8	620 1677 000	Receptacle Panel, BNC	8
	929 7875 001	PC Board	1

Table 7-10. PA Cavity Assembly - 992 5431 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C13,C14	516 0713 000	Capacitor, 500 pF, 15 kV	2
C16	514 0194 000	Capacitor, Variable, 10-100 pF	1
C19,C20,C21	516 0235 000	Capacitor, 1000, pF, Feedthru	3
C22 thru C25	516 0235 000	Capacitor, 1000 pF, 5 kV,	4
L2	914 7670 002	RF Choke Assembly	1
	992 5567 001	Socket/Input Circuit Assembly	1

WARNING: Disconnect primary power prior to servicing.

Table 7-11. Socket/Input Circuit Assembly - 992 5567 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1	516 0436 000	Capacitor, 5 pF, 7.5 kV	1
C2	516 0205 000	Capacitor, 500 pF, 5 kV	1
C9	520 0071 000	Capacitor, Variable, 11-53 pF	1
C11,C12,C17,C18	516 0206 000	Capacitor, 1000 pF, 5 kV	4
J1	929 7616 001	Connector/Cable Assembly - Input	1
L1,L3	494 0004 000	Choke, RF, 7 uH	2
R2,R3	542 0169 000	Resistor, 25 ohm, 25W	2

Table 7-12. Transmitter Control - 992 5432 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
A1	992 5433 001	Digital Logic PC Board Assemnbly	1
A2	992 5434 001	Analog PC Board Assembly	1
A3	992 5435 001	RFI PC Board Assembly	1
A4	992 5436 001	Mother Board Assembly	1
A5	992 5437 001	Status Board Assembly	1
R1	550 0912 000	Potentiometer, 1K ohm	1
R2,R3,R4,R5	550 0067 000	Potentiometer, 10k ohm, 2W, 10%	4
S1	604 0032 000	Switch, Toggle, DPDT	1
S2	604 0911 000	Switch, Toggle, SPDT	1
	929 7186 001	Cable, Ribbon RFI (50)	1
	929 7187 001	Cable, Ribbon Display (34)	1

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2,C3,C4	526 0050 000	Capacitor, 1 uF, 35V	4
C5	526 0325 000	Capacitor, .1 uF, 35V	1
C6	526 0360 000	Capacitor, 220 uF, 15V	1
C7	516 0375 000	Capacitor, .01 uF, 50V	1
C8	526 0050 000	Capacitor, 1 uF, 35V	1
C9	526 0057 000	Capacitor, 100 uF, 20V	1
C10,C11,C12	526 0050 000	Capacitor, 1 uF, 35V	3
C13	526 0325 000	Capacitor, .1 uF, 35V	1
C14	526 0360 000	Capacitor, 220 uF, 15V	1
C15	516 0375 000	Capacitor, .01 uF, 50V	1
C16	526 0048 000	Capacitor, 10 uF, 20V	1
C17	526 0050 000	Capacitor, 1 uF, 35V	1
C18	526 0057 000	Capacitor, 100 uF, 20V	1
C19	526 0360 000	Capacitor, 220 uF, 15V	1
C20	526 0050 000	Capacitor, 1 uF, 35V	1
C21	526 0350 000	Capacitor, 3.9 uF, 35V	1
C22,C23,C24,C25, C26,C27,C28,C29	526 0050 000	Capacitor, 1 uF, 35V	8
C30	526 0325 000	Capacitor, .1 uF, 35V	1
C31	526 0360 000	Capacitor, 220 uF, 15V	1
C32	516 0375 000	Capacitor, .01 uF, 50V	1
C33	526 0050 000	Capacitor, 1 uF, 35V	1
C34	526 0325 000	Capacitor, .1 uF, 35V	1

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C35	526 0360 000	Capacitor, 220 uF, 15V	1
C36	516 0375 000	Capacitor, .01 uF, 50V	1
C38 thru C46	526 0050 000	Capacitor, 1 uF, 35V	9
C47 thru C52	526 0375 000	Capacitor, .01 uF, 50V	6
C53	526 0050 000	Capacitor, 1 uF, 35V	1
CR1 thru CR17	384 0431 000	Diode, 1N4001	17
CR18	386 0135 000	Diode, Zener, 1N4733A	1
CR19,CR20,CR21 CR22,CR23,CR24, CR25,CR26	384 0431 000	Diode, 1N4001	8
CR27	386 0135 000	Diode, Zener, 1N4733A	1
CR28,CR29,CR30, CR31,CR32,CR33, CR34,CR35,CR36, CR37,CR38,CR39, CR40,CR41	384 0431 000	Diode, 1N4001	14
CR43	386 0135 000	Diode, Zener, 1N4733A	1
CR44	382 0321 000	Diode, HP2800	1
CR45,CR47,CR48, CR49,CR50,CR51, CR52,CR54,CR55	384 0431 000	Diode, 1N4001	9
J1,J2,J3,J4,J5, J6,J7,J8,J9,J10	612 0775 000	Jack, PC Mount for .040 Pins	10
K1,K2,K3,K4	574 0351 000	Relay, SPST, Latching	4
P1,P2,P3	610 0679 000	Plug, Shorting	3

WARNING: Disconnect primary power prior to servicing.

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
Q1	380 0189 000	Transistor, 2N3904	1
Q2	380 0125 000	Transistor, 2N4401	1
Q3,Q4,Q5	380 0189 000	Transistor, 2N3904	3
Q6	380 0190 000	Transistor, 2N3906	1
Q7	380 0189 000	Transistor, 2N3904	1
Q8	380 0190 000	Transistor, 2N3906	1
Q9	380 0125 000	Transistor, 2N4401	1
Q10,Q12	380 0190 000	Transistor, 2N3906	2
Q13,Q14,Q15	380 0189 000	Transistor, 2N3904	3
Q16,Q17,Q18,Q19, Q20,Q21	384 0316 000	Transistor, 2N5060	6
Q22,Q23,Q24	380 0189 000	Transistor, 2N3904	3
R1	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R2	540 0890 000	Resistor, 120 ohm, 1/4W, 5%	1
R3	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R4	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R5,R6	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2
R7	540 0982 000	Resistor, 820k ohm, 1/4W, 5%	1
R8	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R9	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R10,R11,R12	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	3
R13	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R14,R15	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R16	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1
R17	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R18,R19	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2
R20	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1
R21	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R22	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R23	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1
R24,R25	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2
R26	540 0958 000	Resistor, 82k ohm, 1/4W, 5%	1
R27	540 0977 000	Resistor, 510k ohm, 1/4W, 5%	1
R28	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R29	540 0960 000	Resistor, 100k ohm, 1/4W, 5%	1
R30	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R31	540 0940 000	Resistor, 15k ohm, 1/4W, 5%	1
R32	540 0949 000	Resistor, 36k ohm, 1/4W, 5%	1
R33	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R34	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R35,R36	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2
R37	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R38	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R39	540 0933 000	Resistor, 7.5k ohm, 1/4W, 5%	1
R40	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R41	540 0898 000	Resistor, 270 ohm, 1/4W, 5%	1
R42	540 0907 000	Resistor, 620k ohm, 1/4W, 5%	1
R43	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1
R44	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R45	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R46,R48	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	2
R49	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R50	540 0943 000	Resistor, 20k ohm, 1/4W, 5%	1
R51	540 0916 000	Resistor, 1.5k ohm, 1/4W, 5%	1
R52	540 0942 000	Resistor, 18k ohm, 1/4W, 5%	1
R53	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R54	540 0934 000	Resistor, 8.2k ohm, 1/4W, 5%	1
R55	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R56,R57	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	2
R58	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
R59	540 0962 000	Resistor, 120k ohm, 1/4W, 5%	1
R60	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	1
R61	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R62	540 0923 000	Resistor, 3k ohm, 1/4W, 5%	1
R65	540 0929 000	Resistor, 5.1k ohm, 1/4W, 5%	1
R66,R67,R68, R69,R70,R71	540 0919 000	Resistor, 2k ohm, 1/4W, 5%	6
R72	540 0922 000	Resistor, 2.7k ohm, 1/4W, 5%	1

Table 7-13. Digital Logic PC Board Assembly - 992 5433 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R73	540 0943 000	Resistor, 20k ohm, 1/4W, 5%	1
R74	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R75 thru R80	540 0931 000	Resistor, 6.2k ohm, 1/4W, 5%	6
R81	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R82	540 0943 000	Resistor, 20k ohm, 1/4W, 5%	1
R83	540 0936 000	Resistor, 10k ohm, 1/4W, 5%	1
R84 thru R89	540 0916 000	Resistor, 1.5k ohm, 1/4W, 5%	6
R90	540 0888 000	Resistor, 100k ohm, 1/4W, 5%	1
R91	540 0945 000	Resistor, 24k ohm, 1/4W, 5%	1
R92	540 0948 000	Resistor, 33k ohm, 1/4W, 5%	1
R93	540 0952 000	Resistor, 47k ohm, 1/4W, 5%	1
U1,U2	382 0260 000	Integrated Circuit, NE555N	2
U3	382 0662 000	Integrated Circuit, MC14013B6P	1
U4	382 0553 000	Integrated Circuit, MC14012BCL	1
U5	382 0662 000	Integrated Circuit, MC14013B6P	1
U6,U7	382 0260 000	Integrated Circuit, NE555N	2
XU1,XU2	404 0673 000	Socket, Integrated Circuit, 8 Pin	2
XU3,XU4,XU5	404 0674 000	Socket, Integrated Circuit, 14 Pin	3
XU6,XU7	404 0673 000	Socket, Integrated Circuit, 8 Pin	2
	943 3212 001	Printed Board	1

Table 7-14. Analog PC Board Assembly - 992 5434 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1	526 0314 000	Capacitor, 33 uF, 10V	1
C2,C3,C5,C6	526 0050 000	Capacitor, 1 uF, 35V	4
C4	526 0048 000	Capacitor, 10 uF, 20V	1
C7	526 0309 000	Capacitor, 22 uF, 35V	1
C8	526 0050 000	Capacitor, 1 uF, 35V	1
C9	526 0311 000	Capacitor, 2.2 uF, 35V	1
C10	526 0057 000	Capacitor, 100 uF, 20V	1
C11	516 0375 000	Capacitor, .01 uF, 50V	1
C12	526 0311 000	Capacitor, 2.2 uF, 35V	1
C13	526 0050 000	Capacitor, 1 uF, 35V	1
C14	516 0375 000	Capacitor, .01 uF, 50V	1
C15,C16	516 0411 000	Capacitor, .1 uF, 50V	2
C17,C18,C19,C20, C21,C22,C23,C24, C25,C26,C27,C28, C29	516 0375 000	Capacitor, .01 uF, 50V	13
CR1,CR2	384 0205 000	Diode, 1N914	2
CR3	386 0082 000	Diode, 1N4744A	1
CR4,CR5,CR6,CR7, CR8,CR9,CR10,CR11, CR12,CR13,CR14, CR15	384 0205 000	Diode, 1N914	12
CR16,CR17	386 0137 000	Diode, Zener, 1N4746A	2
CR18	384 0431 000	Diode, 1N4001	1
CR19	384 0205 000	Diode, 1N914	1
CR20	386 0082 000	Diode, Zener, 1N4744A	1

WARNING: Disconnect primary power prior to servicing.

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
CR21	386 0405 000	Diode, 2N5242B	1
CR22,CR23,CR24, CR25,CR26,CR27	384 0205 000	Diode, 1N914	6
CR30	386 0082 000	Diode, Zener, 1N4744A	1
CR31,CR32	384 0205 000	Diode, 1N914	2
J1,J2,J3	612 0775 000	Jack, PC Mount for .040 Pins	3
P1	610 0679 000	Plug, Shorting, .040 Pins, Insulated	1
Q1,Q2,Q3,Q4,Q5, Q6,Q7,Q8	380 0190 000	Transistor, 2N3906	8
Q9	380 0189 000	Transistor, 2N3904	1
Q10,Q11,Q12,Q13	380 0125 000	Transistor, 2N4401	4
Q15,Q16	380 0189 000	Transistor, 2N3904	2
Q17	380 0183 000	Transistor, MPS U95	1
Q18	380 0190 000	Transistor, 2N3906	1
Q19,Q20	384 0684 000	SCR., C206A, 100V, 3 Ampere	2
Q21	380 0189 000	Transistor, 2N3904	1
R1,R2,R3,R4,R5	540 1356 000	Resistor, Array, 10k ohm	5
R6	540 1251 000	Resistor, 300k ohm, 1/2W, 5%	1
R7	540 0318 000	Resistor, 1k ohm, 1/4W, 1%	1
R8	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1
R9	540 1122 000	Resistor, 47k ohm, 1/2W, 5%	1
R10	548 0414 000	Resistor, 8870 ohm, 1/4W, 1%	1
R11	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R12,R13	548 0414 000	Resistor, 8870 ohm, 1/4W, 1%	2
R14	548 0341 000	Resistor, 33.2k ohm, 1/4W, 1%	1
R15,R16	548 0318 000	Resistor, 1k ohm, 1/4W, 1%	2
R17	540 1251 000	Resistor, 300k ohm, 1/2W, 5%	1
R18	548 0318 000	Resistor, 1k ohm, 1/4W, 1%	1
R19	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1
R20	540 1122 000	Resistor, 47k ohm, 1/2W, 5%	1
R21	548 0318 000	Resistor, 1k ohm, 1/4W, 1%	1
R22	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1
R23,R24	548 0414 000	Resistor, 8870 ohm, 1/4W, 1%	2
R25	540 1322 000	Resistor, 10 Megohm, 1/2W, 10%	1
R26	540 1160 000	Resistor, 22k ohm, 1/2W, 5%	1
R27	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R28	548 1460 000	Resistor, 86.6k ohm, 1/4W, 1%	1
R29	540 1111 000	Resistor, 10k ohm 1/2W, 5%	1
R30,R31	548 0318 000	Resistor, 1k ohm, 1/4W, 1%	2
R32	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R33	540 1160 000	Resistor, 22k ohm, 1/2W, 5%	1
R34	540 1322 000	Resistor, 10 Megohm, 1/2W, 10%	1
R35	540 1159 000	Resistor, 100k ohm, 1/2W, 5%	1
R36,R37	540 1207 000	Resistor, 4.3k ohm, 1/2W, 5%	2
R38	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1

WARNING: Disconnect primary power prior to servicing.

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R39,R40	540 1322 000	Resistor, 10 Megohm, 1/2W, 10%	2
R41	540 1145 000	Resistor, 6.8k ohm 1/2W, 5%	1
R42,R43	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	2
R44	540 1145 000	Resistor, 6.8k ohm, 1/2W, 5%	1
R45,R46	540 1322 000	Resistor, 10 Megohm, 1/2W, 10%	2
R47	540 0067 000	Resistor, 5.6k ohm, 1/2W, 5%	1
R48,R49,R50,R51	540 1160 000	Resistor, 22k ohm, 1/2W, 5%	4
R52	540 1188 000	Resistor, 270 ohm, 1/2W, 5%	1
R53	540 1163 000	Resistor, 300 ohm, 1/2W, 5%	1
R54,R55	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	2
R56,R57	540 1162 000	Resistor, 1 Megohm, 1/2W, 5%	2
R58	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R59	540 1130 000	Resistor, 620 ohm, 1/2W, 5%	1
R60	540 1107 000	Resistor, 20k ohm, 1/2W, 5%	1
R61	540 1115 000	Resistor, 470 ohm, 1/2W, 5%	1
R62	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R63	540 1130 000	Resistor, 620 ohm, 1/2W, 5%	1
R64	540 1107 000	Resistor, 20k ohm, 1/2W, 5%	1
R65	540 1115 000	Resistor, 470 ohm, 1/2W, 5%	1
R66	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R67,R68	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	2
R69	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R70	540 1102 000	Resistor, 100 ohm, 1/2W, 5%	1
R71	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R72,R73	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	2
R74	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R75	540 1102 000	Resistor, 100 ohm, 1/2W, 5%	1
R76	540 1115 000	Resistor, 470 ohm, 1/2W, 5%	1
R77	540 1112 000	Resistor, 47k ohm, 1/2W, 5%	1
R78	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R79	540 0563 000	Resistor, 10 ohm, 2W, 5%	1
R80	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	1
R81	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R82	540 0563 000	Resistor, 10 ohm, 2W, 5%	1
R83	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R84,R85,R86,R87	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	4
R88	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R89	540 1193 000	Resistor, 2.4k ohm, 1/2W, 5%	1
R90	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	1
R91	540 1160 000	Resistor, 22k ohm, 1/2W, 5%	1
R92	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1
R93,R94	540 1159 000	Resistor, 100k ohm 1/2W, 5%	2
R95	540 1122 000	Resistor, 47k ohm 1/2W, 5%	1
R96	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	1

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R97	540 1153 000	Resistor, 8.2k ohm, 1/2W, 5%	1
R98	540 1129 000	Resistor, 1.5k ohm, 1/2W, 5%	1
R99	540 1159 000	Resistor, 100k ohm, 1/2W, 5%	1
R100	540 1359 000	Resistor, Array, 3.3k ohm	1
R101	540 1182 000	Resistor, 2.2k ohm, 1/2W, 5%	1
R102	548 0394 000	Resistor, 5110 ohm, 1/4W, 1%	1
R103,R104	540 1159 000	Resistor, 100k ohm, 1/2W, 5%	2
R105	540 1106 000	Resistor, 6.2k ohm, 1/2W, 5%	1
R106	540 1130 000	Resistor, 620 ohm, 1/2W, 5%	1
R107	540 1153 000	Resistor, 8.2k ohm, 1/2W, 5%	1
R108	540 1130 000	Resistor, 620 ohm, 1/2W, 5%	1
R109	540 1122 000	Resistor, 47k ohm, 1/2W, 5%	1
R110	540 1159 000	Resistor, 100k ohm, 1/2W, 5%	1
R111	540 1122 000	Resistor, 47k ohm, 1/2W, 5%	1
R112	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R113,R114,R115, R116	540 1115 000	Resistor, 470 ohm, 1/2W, 5%	4
U1,U2	382 0719 000	Integrated Circuit, LM324AN	2
U3,U4	382 0415 000	Integrated Circuit, LM324N	2
U5	382 0619 000	Integrated Circuit, CD4050AE	1
U6	382 0618 000	Integrated Circuit, CD4081AE	1
U7	382 0415 000	Integrated Circuit, LM324N	1

WARNING: Disconnect primary power prior to servicing.

Table 7-14. Analog PC Board Assembly - 992 5434 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
U8	382 0618 000	Integrated Circuit, CD4081AE	1
U9	382 0367 000	Integrated Circuit, CD4049AE	1
U10	382 0371 000	Integrated Circuit, MC7912CP	1
XR1,XR2,XR3,XR4 XR5,XR100	404 0675 000	Socket, 16 Pin	6
XU1,XU2,XU3,XU4	404 0674 000	Socket, 14 Pin	4
XU5	404 0675 000	Socket, 16 Pin	1
XU6,XU7,XU8	404 0674 000	Socket, 14 Pin	3
XU9	404 0675 000	Socket, 16 Pin	1
	404 0513 000	Heat Sink for U10	1
	852 8778 001	Printed Board	1

Table 7-15. RFI PC Board Assembly - 992 5435 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1 thru C16, C20 thru C23, C26 thru C33, C38 thru C79, C81 thru C86, C88,C89	516 0074 000	Capacitor, .005 uF, 1 kV	77
J1	610 0740 000	Pin, 36 Circuit	1
J2,J3	610 0768 000	Header, PC 24 Pin	2
J4,J5	610 0769 000	Header, PC 50 Pin	2
L1	494 0218 000	Choke, Wide Band, 180 MHz	1
R1,R2	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	2
R3	540 0856 000	Resistor, 4.7k ohm, 1/4W, 5%	1
R5,R6,R7	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	3
R8,R9,R10,R11, R12,R13	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	6
R14,R15,R16	540 0912 000	Resistor, 100 ohm, 1/4W, 5%	3
R20	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R21,R22,R23,R26, R27,R28,R29,R30, R31,R32,R33	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	11
R34	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R38,R39	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	2
R40	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R41,R42,R43,R44, R45,R46,R47,R48, R49,R50,R51,R52, R53,R54,R55,R56	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	16
R57	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1

WARNING: Disconnect primary power prior to servicing.

Table 7-15. RFI PC Board Assembly - 992 5435 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R57	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R58,R59,R60,R61, R62,R63	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	6
R64	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R65,R66,R67,R68, R69,R70,R71	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	7
R72	540 0856 000	Resistor, 4.7 ohm, 1/4W, 5%	1
R73,R74,R76,R77, R78	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	5
R79	540 0912 000	Resistor, 1k ohm, 1/4W, 5%	1
R81	540 0888 000	Resistor, 100 ohm, 1/4W, 5%	1
R82,R83	540 0864 000	Resistor, 10 ohm, 1/4W, 5%	2
R84	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R85,R86	540 1165 000	Resistor, 3.3k ohm, 1/2W, 5%	2
R87	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
TB1,TB2	614 0687 000	Terminal Board, 12 Terminal	2

Table 7-16. Mother Board Assembly - 992 5436 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2	526 0238 000	Capacitor, 33 uF, 35V, 20%	2
CR1,CR2	384 0431 000	Rectifier, 1N4001	2
J1	610 0770 000	Header, PC 34 Pin	1
J4,J5	610 0769 000	Header, PC 50 Pin	2
XA1,XA2	612 0928 000	Connector, PC Edge, 72 Pin	2
	939 5198 001	Printed Board	1

WARNING: Disconnect primary power prior to servicing.

Table 7-17. Status PC Board Assembly - 992 5437 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
DS1 thru DS12	384 0611 000	LED, Red W/Clear Mtg. Clips	12
DS13 thru DS16	384 0610 000	LED, Green W/Clear Mrg. Clips	4
J1	610 0770 000	PC Header, 34 Pin	1
R1,R2,R3,R4,R5, R6,R7,R8,R9,R10, R11,R12	540 1130 000	Resistor, 620 ohm, 1/2W, 5%	12
R13	540 1109 000	Resistor, 33k ohm, 1/2W, 5%	1
R14,R15	540 1118 000	Resistor, 220 ohm, 1/2W, 5%	2
R16	540 1206 000	Resistor, 1.6k ohm, 1/2W, 5%	1
R17	540 1109 000	Resistor, 33k ohm, 1/2W, 5%	1
R18	540 1206 000	Resistor, 1.6k ohm, 1/2W, 5%	1
R19	540 1109 000	Resistor, 13k ohm, 1/2W, 5%	1
R20	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	1
R21	540 1189 000	Resistor, 9.1k ohm, 1/2W, 5%	1
R22	540 1205 000	Resistor, 1.2k ohm, 1/2W, 5%	1
R23	540 1189 000	Resistor, 9.1k ohm, 1/2W, 5%	1
R24,R25,R26,R27	550 0955 000	Potentiometer, 5k ohm, 1/2W, 10%	4
S1	604 0905 000	Switch, MOM, Push Button	1
S2	604 0903 000	Switch, SPDT, MOM Off	1
S3	604 0904 000	Switch, SPDT, Toggle	1
	843 3256 001	PC Board	1

Table 7-18. Ribbon RFI Cable - 929 7186 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
	612 0929 000	Receptacle, Connector Kit, 50 Pin	1

Table 7-19. Ribbon Display Cable - 929 7187 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
	612 0889 000	Receptacle Kit, 34 Pin	2

Table 7-20. Low Pass Filter/Directional Coupler Assembly - 992 5620 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1	517 0053 000	Capacitor, Variable, .8-23 pF	1
C2	517 0052 000	Capacitor, Variable, .8-11.0 pF	1
C3	517 0053 000	Capacitor, Variable, .8-23 pF	1
C4	500 0803 000	Capacitor, 5 pF, 500V	1
C5	500 0817 000	Capacitor, 47 pF, 500V	1
C6	500 0833 000	Capacitor, 390 pF, 500V	1
C7	500 0842 000	Capacitor, 820 pF, 300V	1
C8	500 0817 000	Capacitor, 47 pF, 500V	1
C9	500 0833 000	Capacitor, 390 pF, 500V	1
C10	500 0842 000	Capacitor, 820 pF, 300V	1
C11	500 0803 000	Capacitor, 5 pF, 500V	1
C12	518 0058 000	Capacitor, Variable, 5.5-18 pF	1
C13,C14,C15	516 0235 000	Capacitor, 1000 pF, Feedthru	3
CR1,CR2	384 0321 000	Diode, HP2800	2
J1,J2	612 0233 000	Receptacle, 'N' UG 58AU	2
L1,L2	829 7108 001	Inductor, 2-1/2 Turn	2
L3	829 7108 002	Inductor, 1-1/2 Turn	1
L4	829 7108 001	Inductor, 2-1/2 Turn	1
L5,L6	494 0388 000	Inductor, 2.2 uH	2
L7	494 0376 000	Choke, RF, .22 uH	1
R1	540 0305 000	Resistor, 75 ohm, 1W, 5%	1
R2	550 0624 000	Potentiometer, 50 ohm, 1/2W, 10%	1
R3	540 0308 000	Resistor, 100 ohm, 1W, 5%	1
	839 5156 001	PC Board	1

WARNING: Disconnect primary power prior to servicing.

Table 7-21. Cabinet Assembly - 992 5438 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
A12	992 5439 001	AC Control Unit	1
A10R1	917 0570 001	Filament Resistor Assembly	1
C1	522 0432 000	Capacitor, 450 uF, 50V	1
C2,C3	524 0155 000	Capacitor, 220 uF, 450V	2
C4,C5	524 0322 000	Capacitor, 15,000 uF, 100V	2
C6	522 0245 000	Capacitor, 75 uF, 25V	1
C7,C8,C9,C10,C11	516 0080 000	Capacitor, .01 uF, 600V	5
CB1	606 0580 000	Circuit Breaker, 2 Pole, 20 Amp.	1
CB2	606 0579 000	Circuit Breaker, 2 Pole, 10 Amp.	1
CB3,CB4	606 0581 000	Circuit Breaker, 3 Pole, 20 Amp.	2
CR1,CR2,CR3	384 0614 000	Rectifier, 70H40A	3
CR4,CR5,CR6	384 0674 000	Rectifier, 70 Ampere, 400 PIV, 70HR40A	3
CR7	386 0078 000	Rectifier, 1N4734A	1
DS1,DS2	396 0183 000	Lamp, #382, 14V, .08 Ampere	2
E2,E3	410 0027 000	Insulator, Round, 1 Inch Dia. X 3.00 Inch Long	2
E4,E5	410 0009 000	Insulator, Round, .5 Dia. X .75 Long	2
E8,E9,E10,E11, E12,E13,E15,E16	614 0401 000	Terminal Insulated, 6-32 Tap Mtg. Hole	8
J1	612 0312 000	Jack, Press In White	1
J2	612 0311 000	Jack, Press In Black	1
K1	570 0242 000	Contactor, 4 Pole, 9 Ampere, 120V, 50/60 Hz	1

Table 7-21. Cabinet Assembly - 992 5438 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
K2	570 0120 000	Contactor, 4 Pole, 40 Ampere, 110V ac	1
K3	574 0395 000	Contactor, 2 Pole, 25 Ampere	1
K4	574 0396 000	Solid State AC Relay, 10 Ampere, 3-28V dc	1
L1	476 0304 000	Inductor, 10 Hy, 400 mA	1
M2	632 1000 000	Multimeter, 0-1 mA dc Movement @ 85 ohms (829 7555 001)	1
M3	632 0999 000	Meter, IPA Power, 0-1 mA dc Movement @ 85 ohms (829 7556 001)	1
M4	632 0569 002	Voltmeter, 0-10 kV	1
M5	632 0645 000	Ammeter, 0-5 Ampere (814 9814 001)	1
M6	632 0667 000	Meter, Power Out	1
R1	548 0313 000	Resistor, 499k ohms, 1W, 1%	1
R2	542 0180 000	Resistor, 1k ohm, 25W	1
R3	542 0216 000	Resistor, 2.5k ohm, 50W	1
R4	540 0608 000	Resistor, 750 ohm, 2W, 5%	1
R5	540 0618 000	Resistor, 2k ohm, 2W	1
R6,R7	540 0668 000	Resistor, 240k ohm, 2W, 5%	2
R8	552 0984 000	Rheostat, 1.5k ohm, 25W	1
R10	548 1173 000	Resistor, 49.9 ohm, 3W, 1%	1
R11,R12,R13,R14, R15	548 1502 000	Resistor, 5 ohm, 10W, 1%	5
R16	540 1115 000	Resistor, 470 ohm, 1.2W, 5%	1
R17	548 1403 000	Resistor, 2.49k ohm, 1/4W, 1%	1

Table 7-21. Cabinet Assembly - 992 5438 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R18	548 1389 000	Resistor, 2.74k ohm, 1/4W, 1%	1
R20,R21	914 3424 001	Multiplier, Meter, MM5	2
R22,R23,R24	548 1184 000	Resistor, 500k ohm, 2W, 1%	3
R25,R26	548 1361 000	Resistor, 10k ohm, 1/4W, 1%	2
R31	550 0059 000	Potentiometer, 500 ohm, 2W, 10%	1
R32	540 0617 000	Resistor, 1.8k ohm, 2W, 5%	1
R33	552 0985 000	Rheostat, 100 ohm, 25W	1
RV1,RV2,RV3	560 0049 000	Varistor, V275LA15A	3
S1,S2,S3,S4	598 0188 000	Switch, Base, 513 0410 000	4
S5	604 0893 000	Switch, Interlock, DPDT	1
S9	604 0397 000	Switch, Air Pressure, Dwyer 1823-2	1
S10	917 0725 001	Switch, Selector, 2 Pole, Positon Rotary	1
S11	917 0724 001	Switch, 1 Pole, 2 Position	1
S12	917 0725 001	Switch, Selector, 2 Pole, 5 Position, Rotary	1
T1	472 1217 000	Transformer, Bias (817 0332 001)	1
T2	474 0090 000	Transformer, Variable, VT8LN	1
T3	472 1215 000	Transformer, Driver (817 0334 001)	1
T4	472 1218 000	Transformer, Filament (817 0331 001)	1
T5	472 0622 000	Transformer, Control, P6377	1
T6	472 0709 000	Transformer, Isolation (815 2648 001)	1

WARNING: Disconnect primary power prior to servicing.

Table 7-21. Cabinet Assembly - 992 5438 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
T7	472 0622 000	Transformer, Control P6377	1
TB1	614 0528 000	Terminal Board, 4 Terminal	1
TB2,TB3	614 0058 000	Terminal Board, 14 Terminal	2
TB5	614 0050 000	Terminal Board, 6 Terminal	1
Z1	384 0595 000	Diode, Bridge, MDA962-2	1
Z2,Z3	384 0167 000	Rectifier, 5 kV, 1 Ampere	2
Z4,Z5	914 7887 001	RF Coupling Loop Assembly	2

WARNING: Disconnect primary power prior to servicing.

Table 7-22. AC Control PC Assembly - 992 5439 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1	500 0754 000	Capacitor, 220 pF, 500V	1
C2	500 0835 000	Capacitor, 470 pF, 500V	1
C3	526 0048 000	Capacitor, 10 uF, 20V	1
C4,C5	516 0453 000	Capacitor, .1 uF, 100V	2
C6	500 0754 000	Capacitor, 220 pF, 500V	1
C7,C8	526 0050 000	Capacitor, 1 uF, 35V	2
C9,C10	516 0084 000	Capacitor, .02 uF, 600V	2
C11	516 0419 000	Capacitor, .05 uF, 500V	1
C12	516 0084 000	Capacitor, .02 uF, 600V	1
C13	516 0419 000	Capacitor, .05 uF, 500V	1
C14	516 0084 000	Capacitor, .02 uF, 600V	1
C15	516 0419 000	Capacitor, .05 uF, 500V	1
C16	516 0084 000	Capacitor, .02 uF, 600V	1
C17	516 0419 000	Capacitor, .05 uF, 500V	1
C18	516 0084 000	Capacitor, .02 uF, 600V	1
C19	516 0419 000	Capacitor, .05 uF, 500V	1
C20	526 0048 000	Capacitor, 10 uF, 20V	1
C21	526 0033 000	Capacitor, 47 uF, 20V	1
C22,C23	500 0912 000	Capacitor, 820 pF, 500V	2
CR1	384 0205 000	Diode, 1N914	1
CR2	386 0399 000	Diode, Zener, 1N5231B	1
CR3,CR4,CR5	384 0431 000	Diode, 1N4001	3

Table 7-22. AC Control PC Assembly - 992 5439 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
K1,K2	574 0156 000	Relay, 4 PDT, 12V dc	2
L1,L2,L3,L4,L5, L6	494 0218 000	Choke, Wide Band, 180 MHz	6
Q1	380 0590 000	Transistor, 2N6294	1
Q2,Q3,Q4,Q5,Q6	384 0351 000	Rectifier, 2N5756	5
Q7	380 0189 000	Transistor, 2N3904	1
Q8	380 0190 000	Transistor, 2N3906	1
R1	548 0814 000	Resistor, 93.1 ohm, 1/4W, 1%	1
R2	548 0869 000	Resistor, 604 ohm, 1/4Wm 1/5	1
R3,R4	548 1506 000	Resistor, 1.27k ohm, 1/4W, 1%	2
R5	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R6	540 1116 000	Resistor, 1k ohm, 1/2W, 5%	1
R7	540 1127 000	Resistor, 820 ohm, 1/2W, 5%	1
R8	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
R9	550 0812 000	Potentiometer, 100 ohm, 1/2W, 10%	1
R10	540 1180 000	Resistor, 360 ohm, 1/2W, 5%	1
R11	540 1118 000	Resistor, 220 ohm, 1/2W, 5%	1
R12	548 0712 000	Resistor, 249 ohm, 1/4W	1
R13	548 0279 000	Resistor, 2k ohm, 1/4W, 1%	1
R14	540 1111 000	Resistor, 10k ohm, 1/2W, 5%	1
R15	540 1104 000	Resistor, 2k ohm, 1/2W, 5%	1
R16 thru R19	540 1193 000	Resistor, 2.4k ohm, 1/2W, 5%	4
R20	540 1118 000	Resistor, 220 ohm, 1/2W, 5%	1

Table 7-22. AC Control PC Assembly - 992 5439 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R21,R22,R23	540 1115 000	Resistor, 470 ohm, 1/2W, 5%	3
R24,R25	540 1111 000	Resistor, 10k ohm 1/2W, 5%	2
R26	540 1114 000	Resistor, 4.7k ohm, 1/2W, 5%	1
TB1,TB2	614 0711 000	Terminal Board, 10 Terminal	2
TB3	614 0712 000	Terminal Board, 5 Terminal	1
U1	382 0631 000	Integrated Circuit, AD536J	1
U2	382 0475 000	Integrated Circuit, LM317K	1
XF1A,XF1B	402 0129 000	Clip, Fuse, 102070	2
XK1,XK2	404 0161 000	Socket, Relay; 9KH2	2
XU1	404 0674 000	Socket, Integrated Circuit, 14 Pin	1
	404 0198 000	Transistor Pad for Q2 through Q6	5
	404 0498 000	Heat Sink for U2	1
	404 0528 000	Heat Sink for Q2,Q3	2
	843 3322 001	Printed Board	1

WARNING: Disconnect primary power prior to servicing.

Table 7-23. Resistor Assembly - 917 0570 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R1	548 0319 000	Resistor, 300 ohm, 1W, 5%	1
	839 5129 001	PC Board	1

WARNING: Disconnect primary power prior to servicing.

Table 7-24. IPA Frame Assembly - 992 5351 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
1A7	992 5350 001	Mother Board Assembly	1
1A8	992 5349 001	Combiner/Splitter Assembly	1
	929 4967 001	Cable, 2 Port to 8 Port & Driver Mother Board	1
	929 4967 002	Cable, 2 Port to 8 Port & Driver Mother Board	1
	929 4967 003	Cable, 2 Port to 8 Port & Driver Mother Board	1
	929 4968 001	Cable, Mother Board & Amplifier Output	1
	929 4969 001	Cable, Combiner/Splitter Input	1
	929 4966 001	Cable, Input to RF Amplifier Mother Board	1
	929 4968 002	Cable, Mother Board & Amplifier Output	1
	929 4968 003	Cable, Mother Board & Amplifier Output	1
	929 4968 004	Cable, Mother Board & Amplifier Output	1
	929 4968 005	Cable, Mother Board & Amplifier Output	1
	929 4968 006	Cable, Mother Board & Amplifier Output	1
	929 4968 007	Cable, Mother Board & Amplifier Output	1
	929 4968 008	Cable, Mother Board & Amplifier Output	1

Table 7-25. Combiner/Splitter Assembly - 992 5349 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2,C3,C4,C5, C6,C7,C8	500 0803 000	Capacitor, 5 pF, 500V	8
C9,C10	500 1234 000	Capacitor, 150 pF, 350V	2
C11,C12,C13,C14, C15,C16,C17,C18	500 1231 000	Capacitor, 47 pF, 350V	8
C19	500 1234 000	Capacitor, 150 pF, 350V	1
C20	500 0800 000	Capacitor, 1 pF, 500V	1
C21,C22,C23,C24	500 0803 000	Capacitor, 5 pF, 500V	4
C25,C26,C27,C28	500 0803 000	Capacitor, 5 pF, 500V	4
C29	500 1231 000	Capacitor, 47 pF, 350V	1
C30	500 1229 000	Capacitor, 22 pF, 350V	1
C31	500 1230 000	Capacitor, 33 pF, 350V	1
R1 thru R16	540 0580 000	Resistor, 51 ohm, 2W, 5%	16
R17,R18	540 1341 000	Resistor, 22 ohm, 30W, 10%	2
R19,R20,R21	540 0598 000	Resistor, 300 ohm, 2W, 5%	3
J1,J2,J3	620 1677 000	Receptacle Panel, BNC	3
	939 4820 001	PC Board Assembly	1
	402 0004 000	Fuse Clip	4
	929 4963 001	2 Port Combiner Transformer Cable	2
	929 4962 001	8 Port Splitter Interconnect Coax	8
	929 4970 001	8 Port Splitter Transformer	1
	929 4973 001	2 Port Combiner, Tapped Trans- former	1

Table 7-26. IPA Mother Board Assembly - 992 5350 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
C1,C2,C3,C4,C5, C6,C7	500 0833 000	Capacitor, 390 pF, 500V	7
F1,F2,F3,F4,F5	398 0140 000	Fuse, Fast, 15 Ampere, 250V	5
J21	610 0703 000	Connector, 6 Pin	1
J22	610 0746 000	Connector, 20 Pin	1
R1	540 1151 000	Resistor, 10 ohm, 1/2W, 5%	1
R2,R3	540 1188 000	Resistor, 270 ohm, 1/2W, 5%	2
R4,R5	540 1151 000	Resistor, 10 ohm, 1/2W, 5%	2
R6	540 1112 000	Resistor, 510 ohm, 1/2W, 5%	1
XA1 thru XA5	612 0887 000	Connector, 72 Contact	5
	843 3046 001	PC Board	1

Table 7-27. High Voltage Power Supply - 992 5428 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
B1	430 0031 000	Blower, Caravel, CL3T2, 230V, 50/60 Hz, 1 PH	1
B2	436 0061 000	Motor, Reversible, 1 RPM, 115V, 60 Hz, 5W	1
C1	508 0535 000	Capacitor, .1 uF, 3 kV	1
C2,C3	510 0560 000	Capacitor, 12 uF, 2 kV	2
C4	510 0471 000	Capacitor, 5.5 uF, 15 kV	1
C5	--- ---- ---	Capacitor, .5 uF, 400V dc (Supplied with Motor B2)	1
C6	508 0534 000	Capacitor, .02 uF, 30 kV	1
CB1	606 0579 000	Circuit Breaker, 10 Ampere, 3 Pole	1
CB2	606 0552 000	Circuit Breaker, 3 Ampere, 1 Pole	1
K1,K2	582 0034 000	Relay, Mag Overload, 600V, AC Max, Open Type NC Contacts	2
K3	570 0240 000	Contactor, 200 Ampere, 3 Pole, 120V ac, 60 Hz, 110V ac, 50 Hz	1
K4	570 0120 000	Contactor, 110V, 40 Ampere, 4 Pole 50/60 Hz	1
L1	476 0270 000	Reactor, 2 HY, 5A dc	1
L2,L3	476 0296 000	Reactor, Filter, 10 Hy, 500 mA (814 9865 001)	2
R1,R2,R3	542 0282 000	Resistor, 1 ohm, 100W, 5%	3
R4	540 1200 000	Resistor, 110 ohm, 50W, 10%	1
R5	540 0837 000	Resistor, 250 ohm, 94W, 10%	1
R6	542 0169 000	Resistor, 25 ohm, 25W	1
R7	542 0305 000	Resistor, 20k ohm, 100W, 5%	1

Table 7-27. High Voltage Power Supply - 992 5428 001 (Continued)

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
R8	542 0325 000	Resistor, 1k ohm, 160W, 5%	1
R9	542 0354 000	Resistor, 50 ohm, 200W, 5%	1
R10	540 1167 000	Resistor, 5 ohm, 180W, 10%	1
R11	542 0305 000	Resistor, 20k ohm, 100W, 5%	1
R12,R13,R14,R15, R16	542 0312 000	Resistor, 100k ohm, 100W	5
R18	542 0356 000	Resistor, 100 ohm, 200W, 5%	1
R19	540 0837 000	Resistor, 250 ohm, 94W, 10%	1
R21	542 0169 000	Resistor, 25 ohm, 25W	1
S1A/S1B, S2,S3, S4A/S4B,S5A/S5B	604 0450 000	Switch, Precision, DPDT	5
S9	992 5480 001	Switch, HV Shorting Crowbar Assembly	1
S12,S13	604 0624 000	Switch, Micro, SPDT	2
T1	472 1219 000	Transformer, Plate (817 0330 001)	1
T2	474 0022 000	Transformer, Auto Variable, Input: 120V, 50/60 Hz Output: 0-140V @ 10 Ampere	1
T3	472 1216 000	Transformer, Screen(817 0333 001)	1
TB1	614 0058 000	Terminal Board, 14 Terminal	1
TB3	614 0003 000	Terminal Board, 3 Terminal	1
Z1,Z2,Z3	384 0650 000	Rectifier, HV, 26 kV, 2.5 Ampere	3
Z4,Z5,Z6,Z7	384 0167 000	Rectifier, Screen 5 kV, 1 Ampere	4
Z8	929 7733 001	Resistor, Diode Assembly	1
	306 0056 000	Nut, Cap, 1/4-20	2

Table 7-28. Resistor/Diode Assembly - 929 7733 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
CR1,CR2,CR3	386 0169 000	Diode, Zener, 1N5352A	3
R20,R22	540 0611 000	Resistor, 1k ohm, 2W, 5%	2
R23	548 1138 000	Resistor, 6.19k ohm, 1/4W, 1%	1
	929 7619 001	PC Board	1

Table 7-29. HV Shorting Assembly - 992 5480 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
L1,L2	590 0037 000	Solenoid, 240V, 60 Hz	2
	916 4954 002	Ground Strap for E3,E4	2
	816 9163 001	Adaptor, Solenoid for E3,E4	2
	817 0136 002	Contact for E1,E2	2

Table 7-30. Extender Board for Controller - 992 5646 001

REF. SYMBOL	HARRIS PART NO.	DESCRIPTION	QTY.
	612 0928 000	Connector, Edge, 72 Pin	1
	843 3382 001	PC Board	1

WARNING: Disconnect primary power prior to servicing.

SECTION VIII

DIAGRAMS

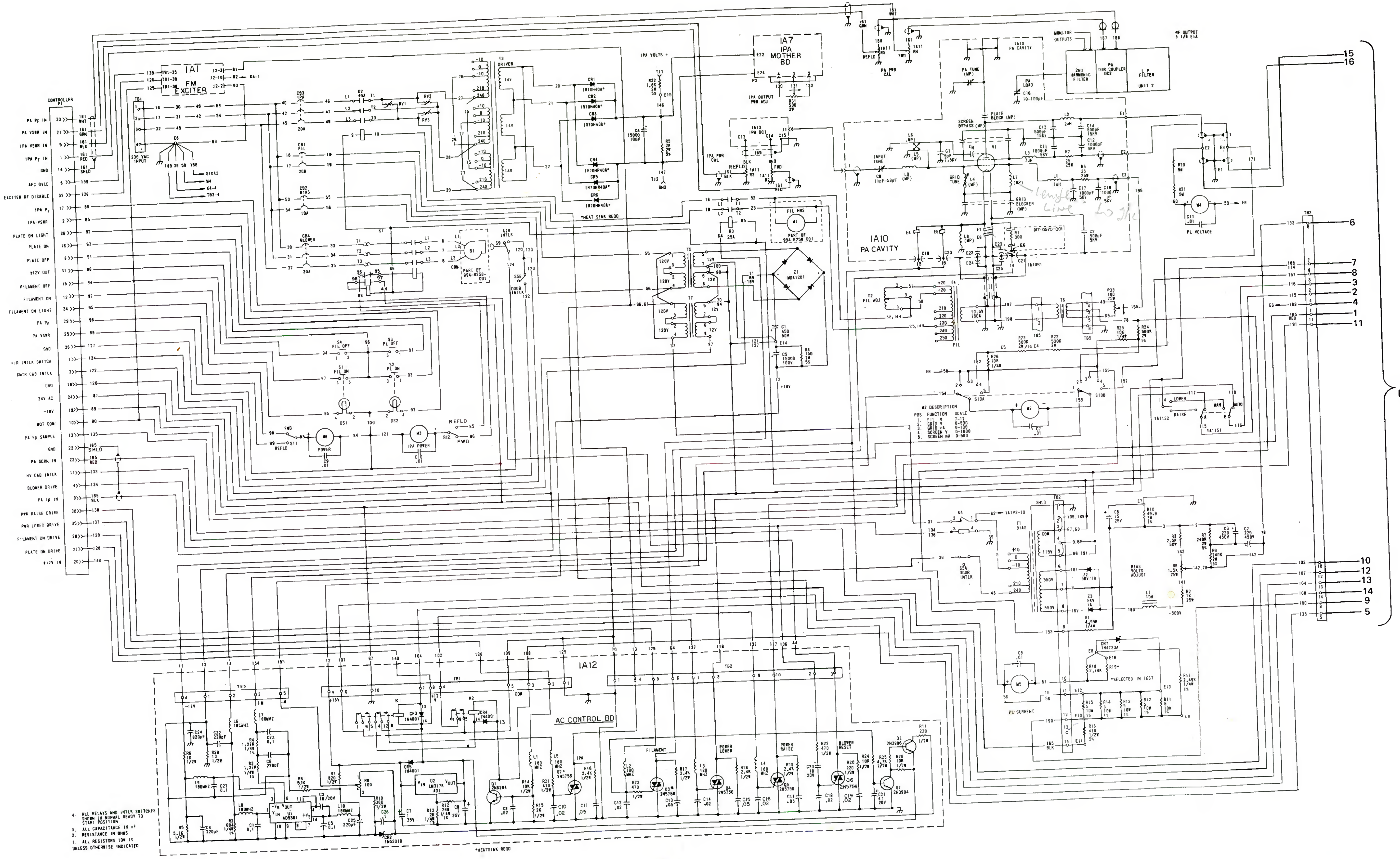
8-1. INTRODUCTION

8-2. This section provides schematic, interconnection, and wiring diagrams required for maintenance of the FM-25K Transmitter. The following diagrams are contained in this section.

Figure	Title	Number	Page
8-1	Main Cabinet Schematic Diagram, FM-25K Transmitter	852 8806 001	8-3/8-4
8-2	Schematic Diagram, Digital, Analog, and Status Boards	852 8792 001	8-5/8-6
8-3	Schematic Diagram, Logic Section Motherboard	852 8808 001	8-7/8-8
8-4	Schematic Diagram, RFI Filter Assembly	852 8807 001	8-9/8-10
8-5	PA Efficiency Curve	1859-9	8-11/8-12
8-6	Schematic Diagram, IPA Section Motherboard	852 8735 001	8-13/8-14
8-7	Schematic Diagram, IPA Combiner/Splitter	839 4830 001	8-15/8-16
8-8	Schematic Diagram, IPA RF Amplifier Module	843 3059 001	8-17/8-18
8-9	Schematic Diagram, IPA 8 Port Combiner	839 4913 001	8-19/8-20
8-10	Schematic, IPA Low-Pass Filter and Directional Coupler	839 5303 001	8-21/8-22
8-11	Main Cabinet Transformer Wiring Diagram	1859-17	8-23/8-24
8-12	High Voltage Cabinet Transformer Wiring Diagram	1859-19	8-25/8-26
8-13	Wire List, Main Transmitter Cabinet (Sheet 1 of 8)	817 0591 001	8-27/8-28
8-13	Wire List, Main Transmitter Cabinet (Sheet 2 of 8)	817 0591 001	8-29/8-30
8-13	Wire List, Main Transmitter Cabinet (Sheet 3 of 8)	817 0591 001	8-31/8-32
8-13	Wire List, Main Transmitter Cabinet (Sheet 4 of 8)	817 0591 001	8-33/8-34

WARNING: Disconnect primary power prior to servicing.

Figure	Title	Number	Page
8-13	Wire List, Main Transmitter Cabinet (Sheet 5 of 8)	817 0591 001	8-35/8-36
8-13	Wire List, Main Transmitter Cabinet (Sheet 6 of 8)	817 0591 001	8-37/8-38
8-13	Wire List, Main Transmitter Cabinet (Sheet 7 of 8)	817 0591 001	8-39/8-40
8-13	Wire List, Main Transmitter Cabinet (Sheet 8 of 8)	817 0591 001	8-41/8-42
8-14	Wire List, High Voltage Power Supply (Sheet 1 of 2)	817 0548 001	8-43/8-44
8-14	Wire List, High Voltage Power Supply (Sheet 2 of 2)	817 0548 001	8-45/8-46



CONTINUED ON PAGE 8-3/8-4B

FIGURE 8-1. SCHEMATIC DIAGRAM
MAIN CABINET FM-25K TRANSMITTER
852 8806 001

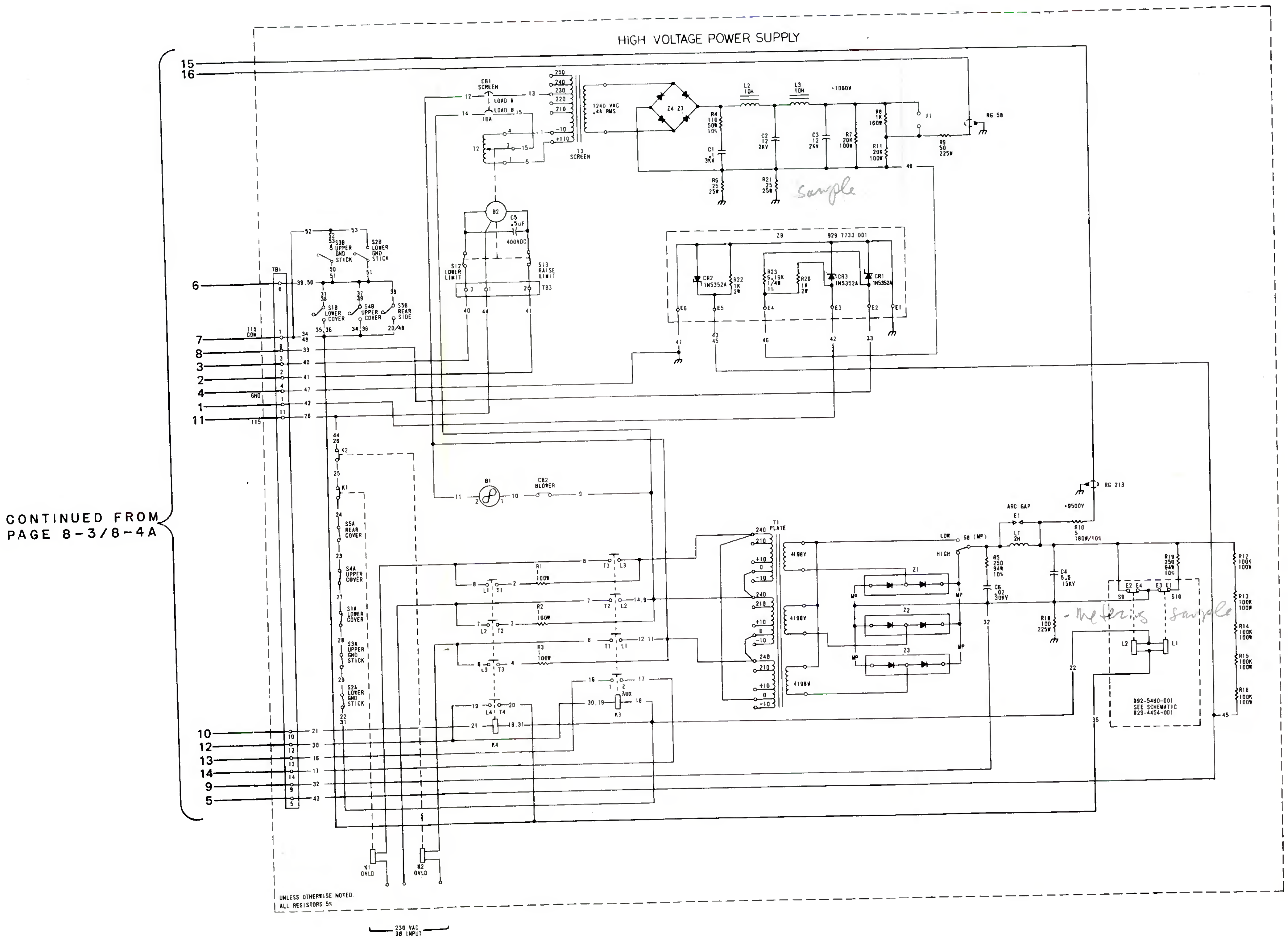
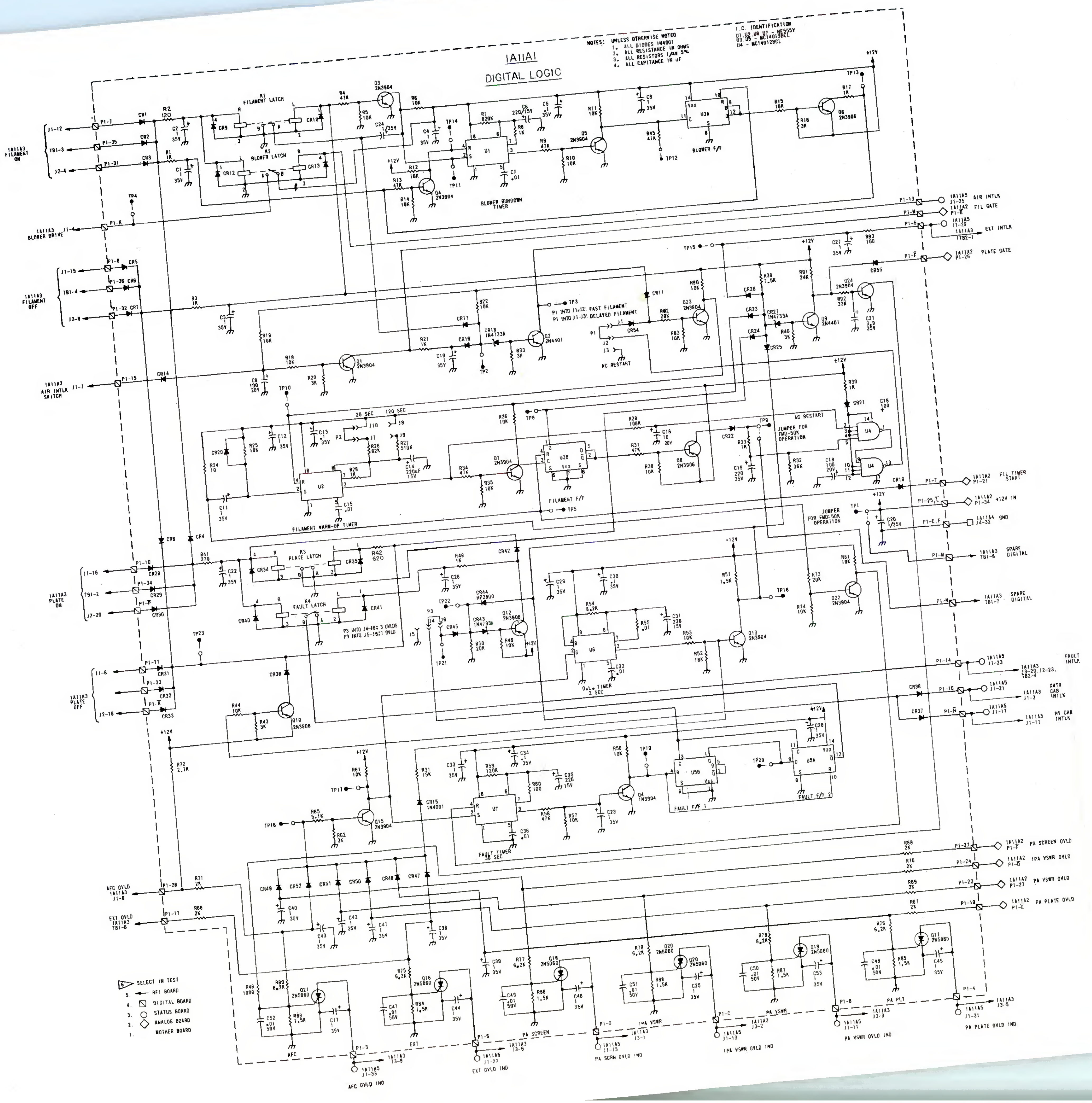


FIGURE 8-1. SCHEMATIC DIAGRAM
MAIN CABINET FM-25K TRANSMITTER
852 8806 001



CONTINUED ON PAGE 8-5/8-6B

FIGURE 8-2. SCHEMATIC DIAGRAM
DIGITAL, ANALOG, AND STATUS BOARDS
852 8792 001

CONTINUED FROM PAGE 8-5/8-6A

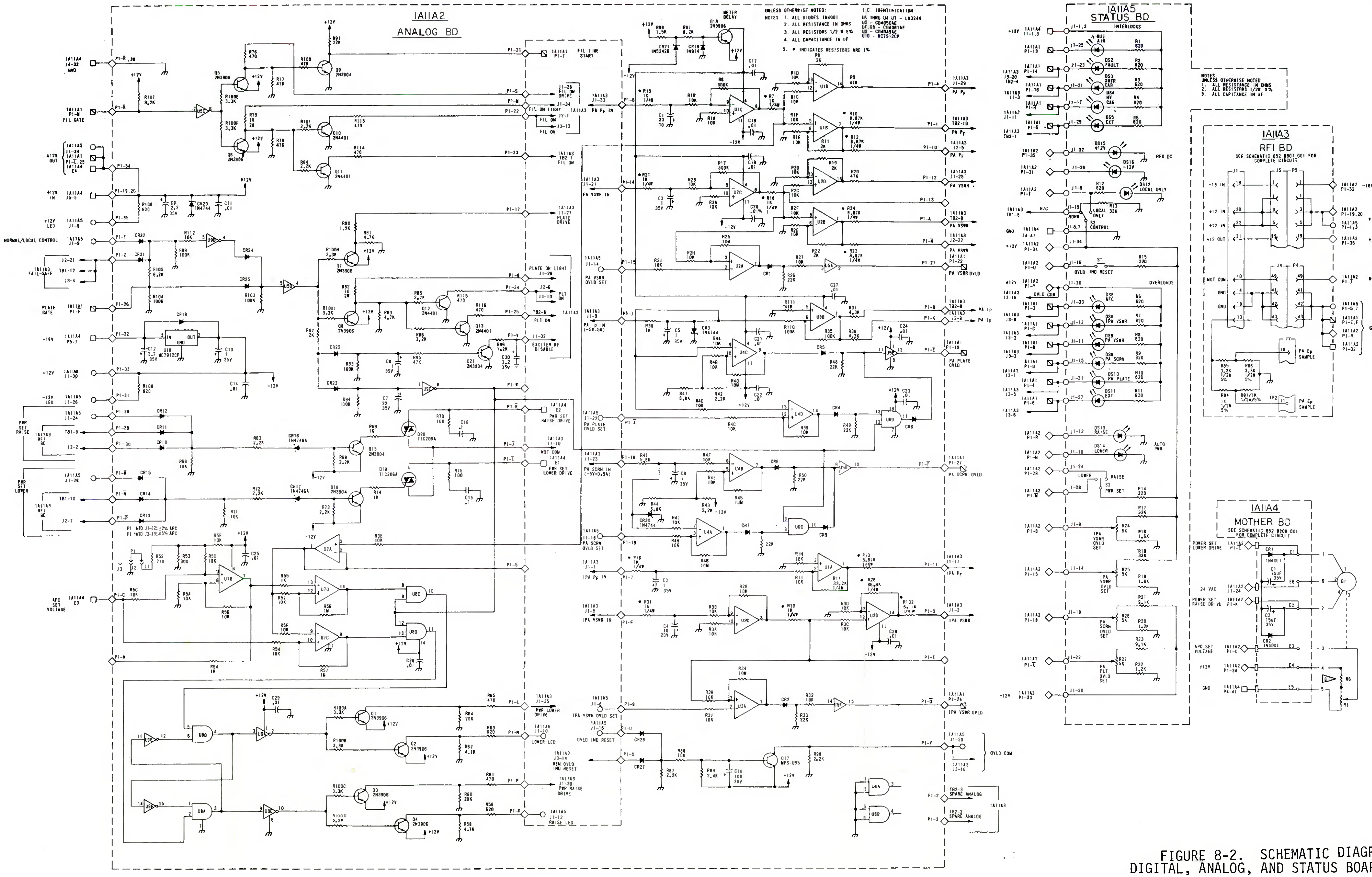


FIGURE 8-2. SCHEMATIC DIAGRAM
DIGITAL, ANALOG, AND STATUS BOARDS
852 8792 001

1A1A4
MOTHER BD

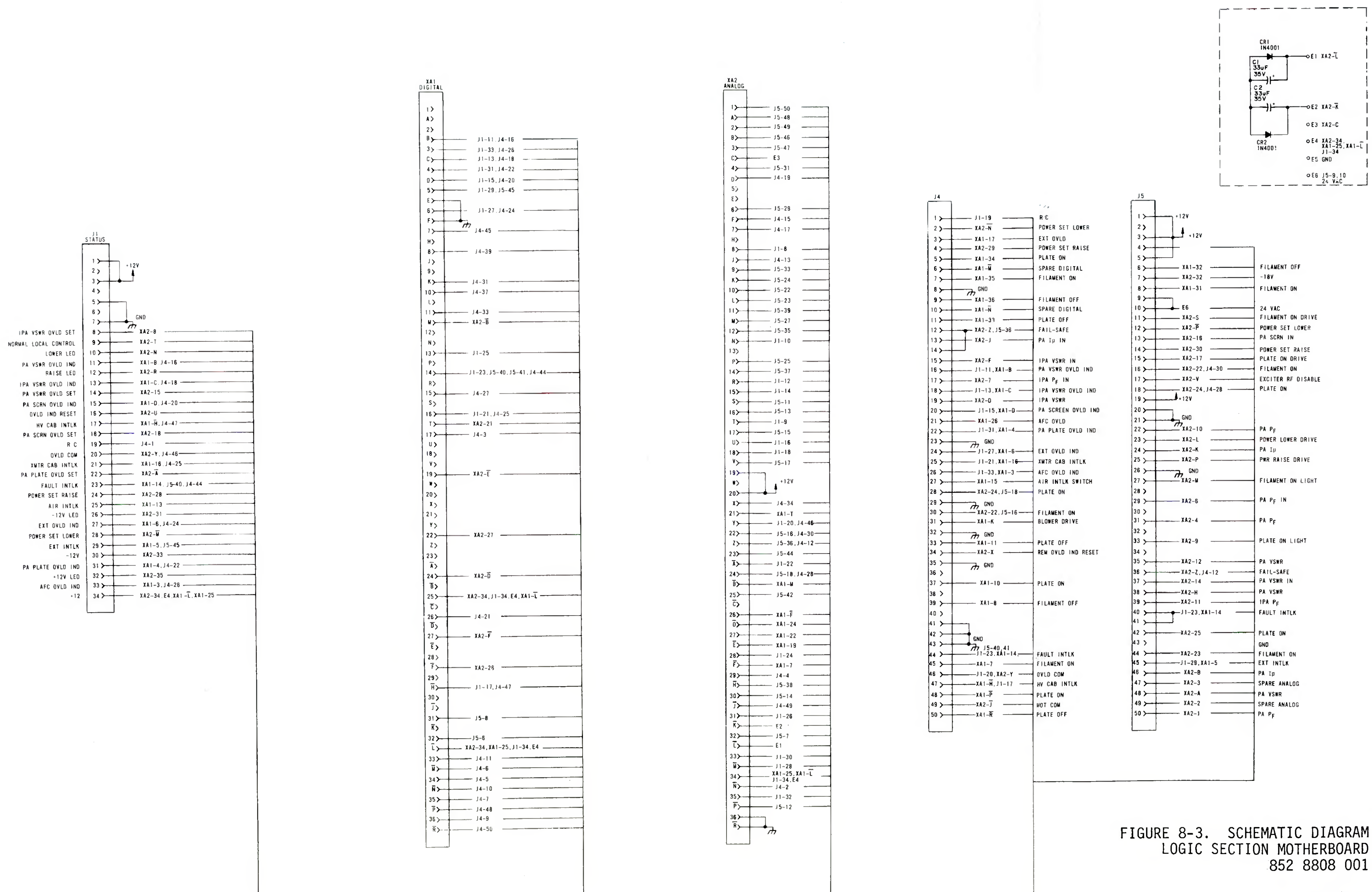


FIGURE 8-3. SCHEMATIC DIAGRAM
LOGIC SECTION MOTHERBOARD
852 8808 001

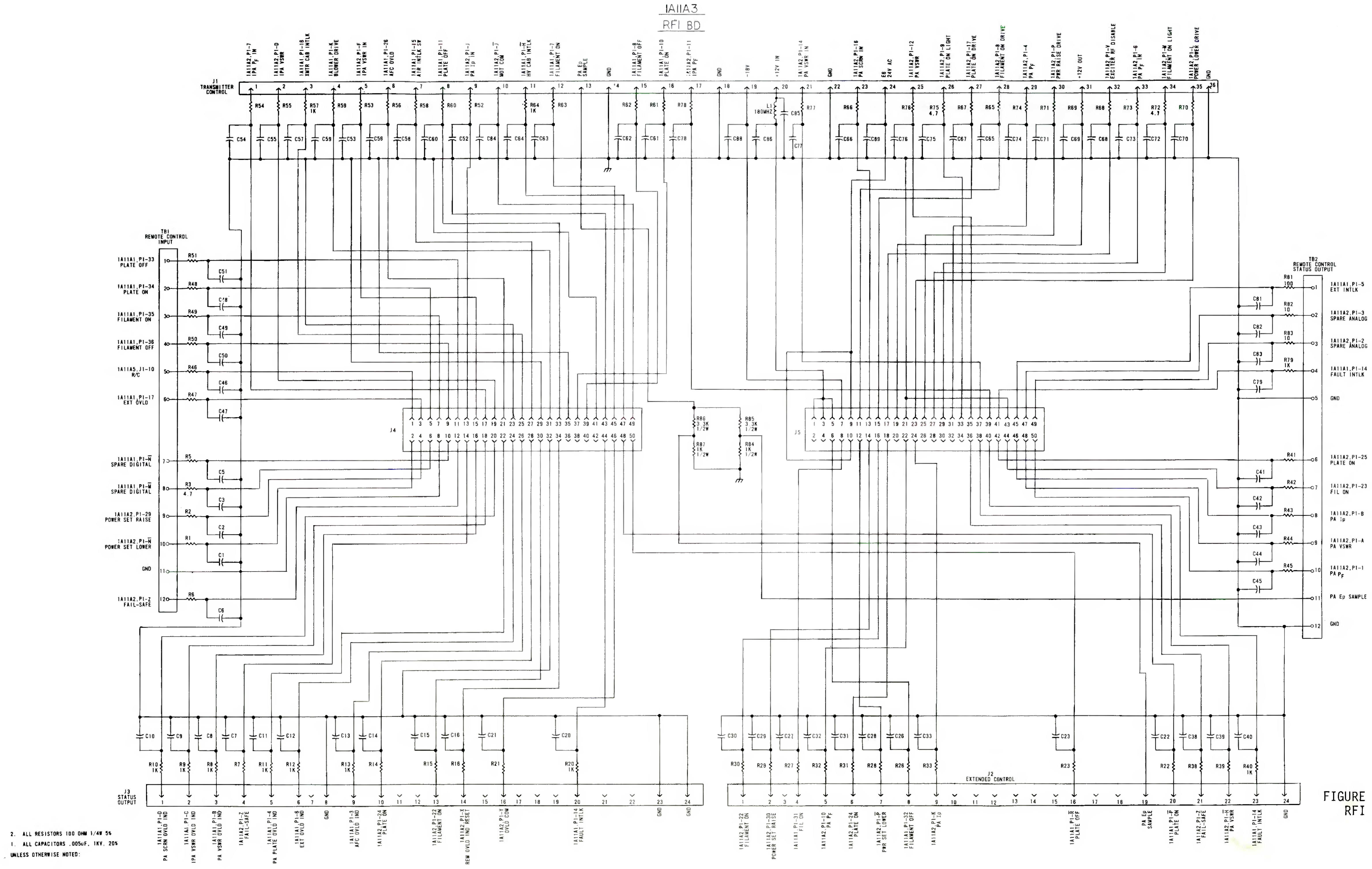


FIGURE 8-4. SCHEMATIC
RFI FILTER ASSEMBLY
852 8807 001

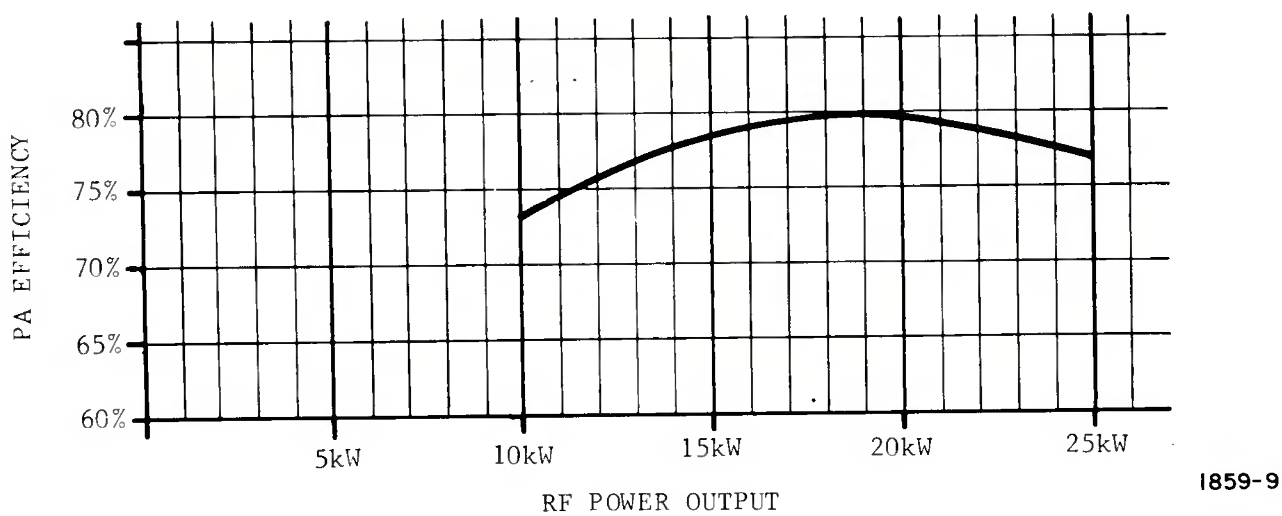
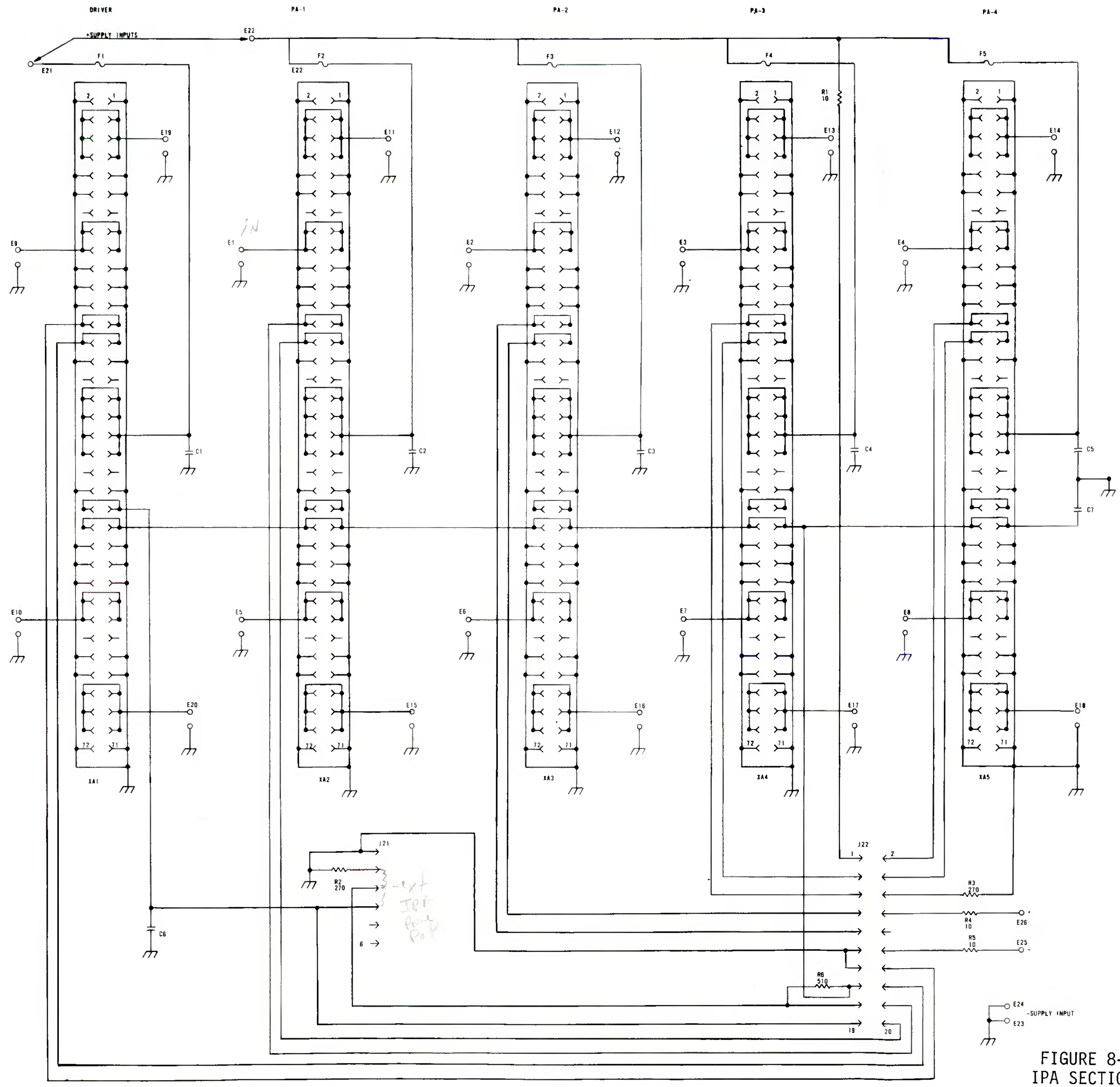


FIGURE 8-5. PA EFFICIENCY CURVE



XA1 - XA5

1-2 GRD
3-4 RF OUT
5-6 RF OUT
7-8 RF OUT
9-10 GRD
11-12 GRD
13-14
15-16 RF IN
17-18 RF IN
19-20 GRD
21-22 GRD
23-24 GRD
25-26 V EMIT MTR
27-28 V REG MTR
29-30 GRD
31-32
33-34 V+IN
35-36 V+IN
37-38 V+IN
39-40 V+IN
41-42
43-44 GRD
45-46 V REF
47-48 V NON-INV
49-50 GRD
51-52 GRD
53-54 GRD
55-56 RF IN
57-58 RF IN
59-60
61-62 GRD
63-64 GRD
65-66 RF OUT
67-68 RF OUT
69-70 RF OUT
71-72 GRD

J22

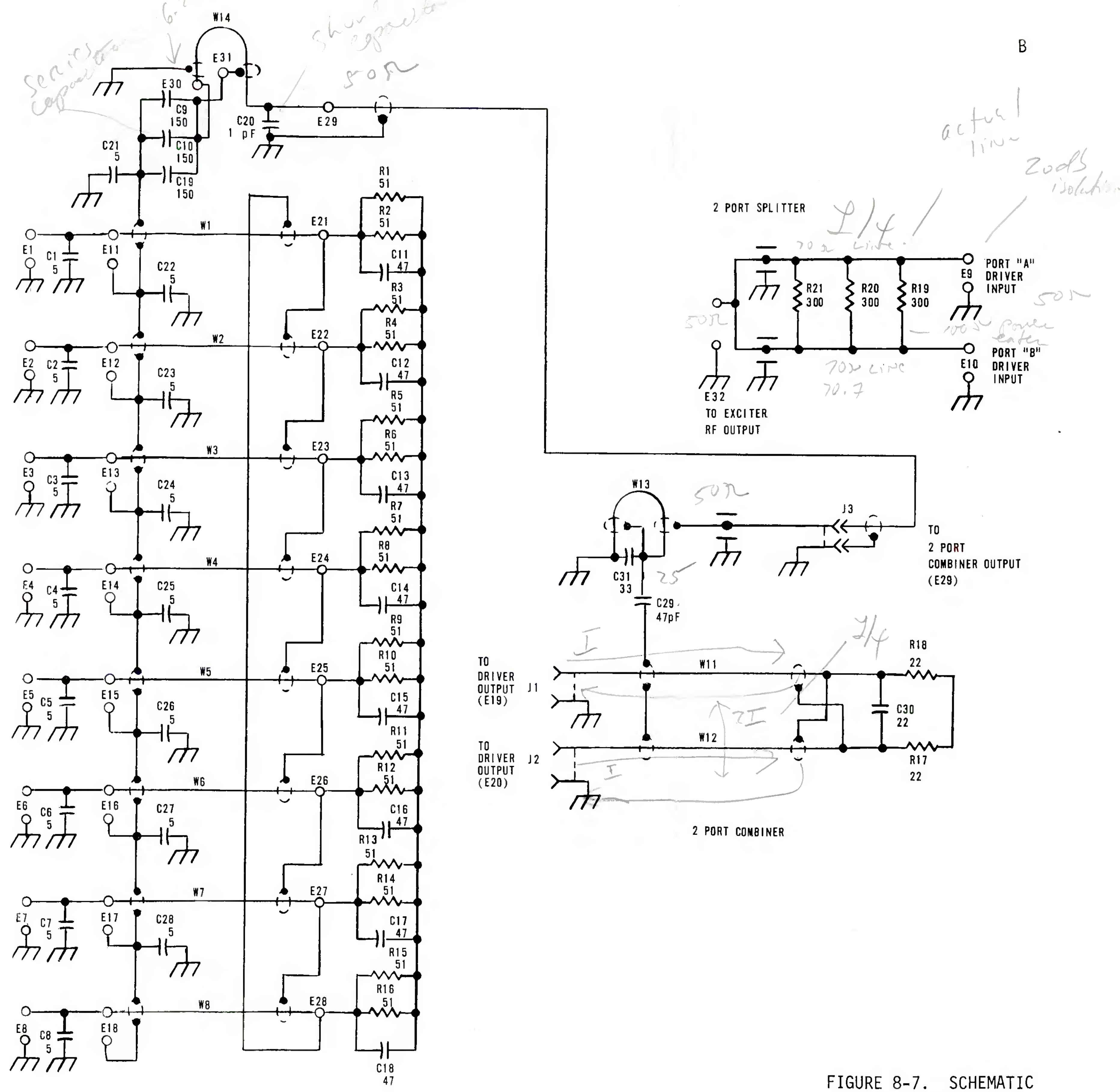
1 V IN MTR
2 V EMIT-A5
3 V REG- A4
4 V REG-A5
5 V EMIT-A4
6 POT CCW
7 V REG-A3
8 MTR SHUNT +
9 V EMIT-A3
10--
11 GRD
12 MTR SHUNT —
13 GRD
14 V EMIT-A1
15 TURN OFF
16 V REG-A1
17 POT WIPER
18 V EMIT-A2
19 POT CW
20 V REG-A2

2. ALL RESISTORS ARE 1/2 WATT 5%
1 ALL CAPACITORS ARE 390pF 500V

NOTES
J21 NOT USED ON FM300
F1 THRU F5 ARE 15AMP
E21 THRU E24 #10-32 STUDS
E25 & E26 #6-32 STUDS

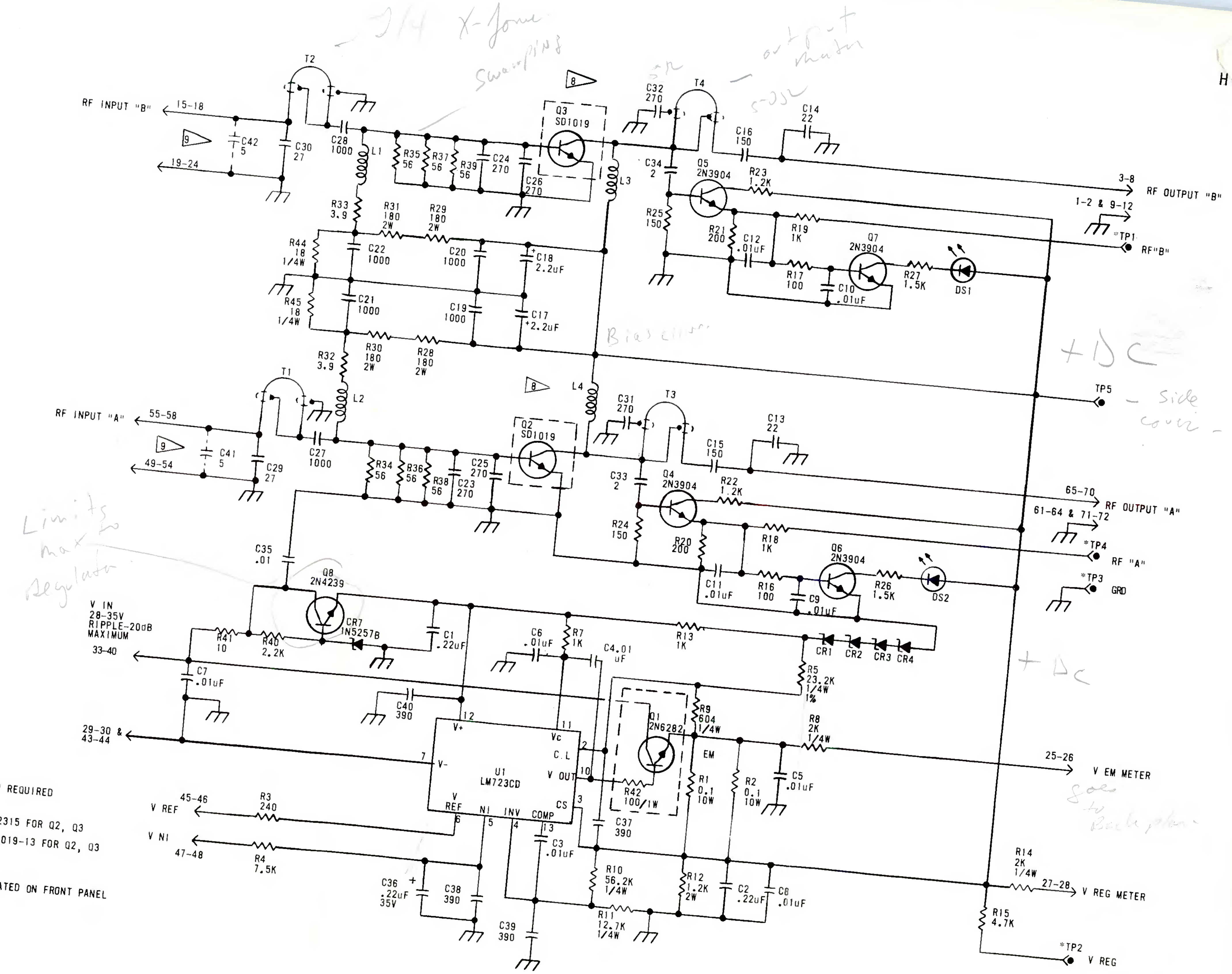
FIGURE 8-6. SCHEMATIC
IPA SECTION MOTHERBOARD
852 8735 001

B



3. CAPACITANCE IN pF
2. RESISTANCE IN OHMS
1. RESISTORS ARE 2W 5%
UNLESS OTHERWISE NOTED:

FIGURE 8-7. SCHEMATIC
IPA COMBINER/SPLITTER
839 4830 001



UNLESS OTHERWISE NOTED:

1. RESISTORS ARE 1/2W 5%
2. RESISTANCE IN OHMS
3. CAPACITANCE IN pF
4. INDUCTANCE IN uH
5. DIODES ARE 1N5231B
6.
7. * TP1, TP2, TP3 & TP4 LOCATED ON FRONT PANEL

8 HARRIS P/N 992-5352-001 USES CD2315 FOR Q2, Q3 2K, 1/4W, 1% FOR R14
992-5352-002 USES SD1019-13 FOR Q2, Q3 2K, 1/4W, 1% FOR R14

9 5μF MAY BE ADDED WHEN REQUIRED

FIGURE 8-8. SCHEMATIC
IPA RF AMPLIFIER MODULE
843 3059 001

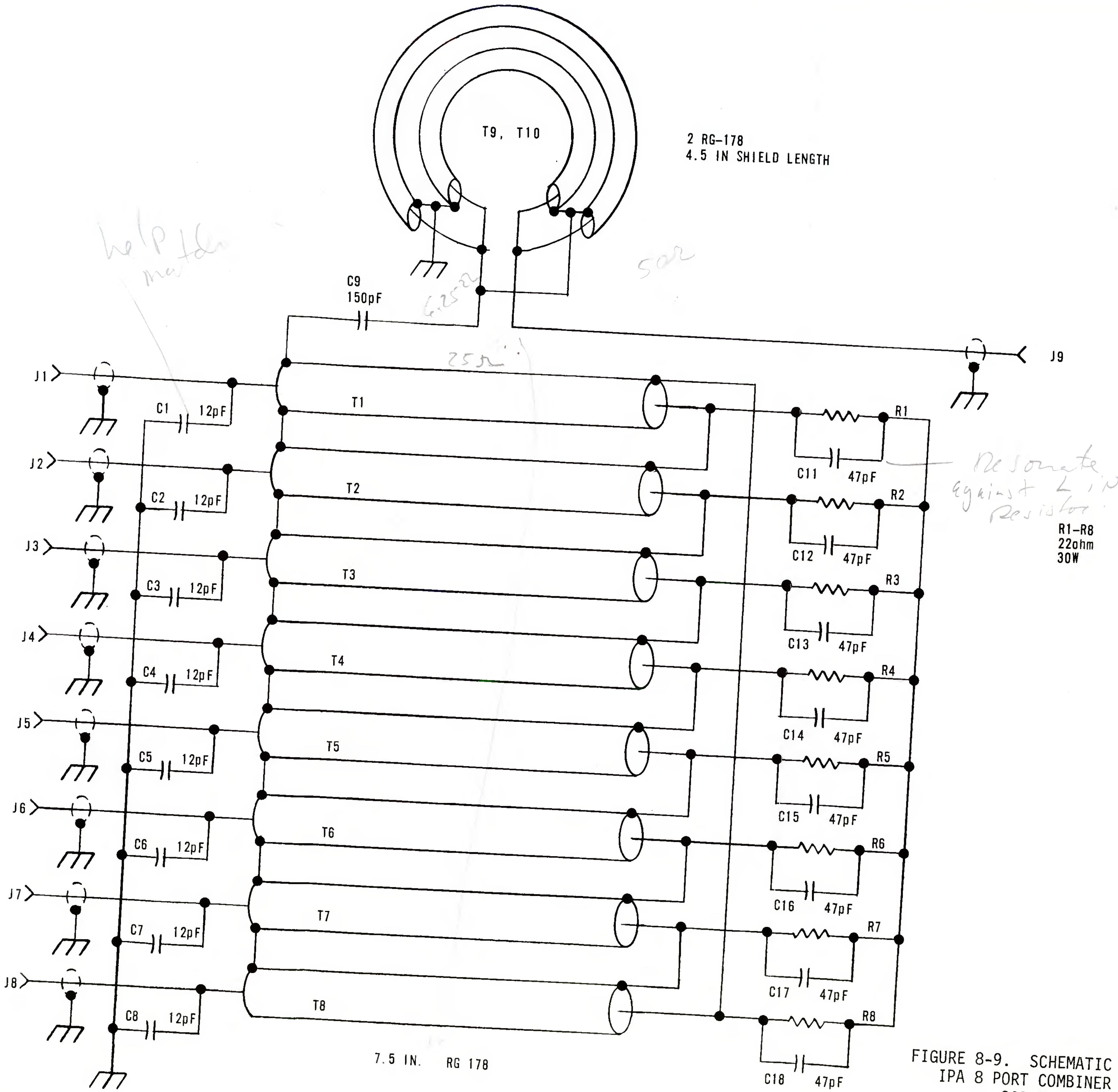
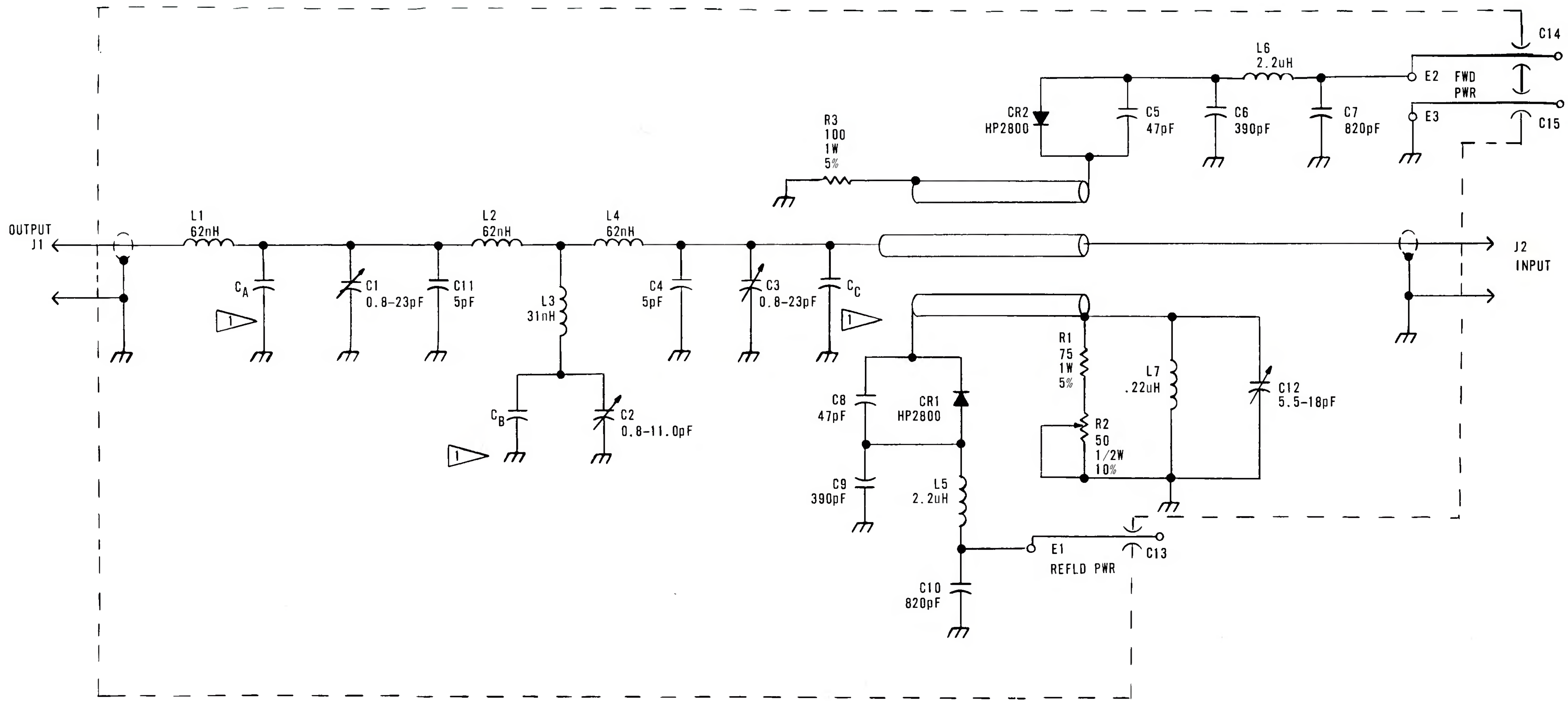


FIGURE 8-9. SCHEMATIC
IPA 8 PORT COMBINER
839 4913 001



C_A, C_B, C_C, PRINTED CIRCUIT CAPACITORS

FIGURE 8-10. SCHEMATIC
IPA LOW-PASS FILTER AND
DIRECTIONAL COUPLER
839 5303 001

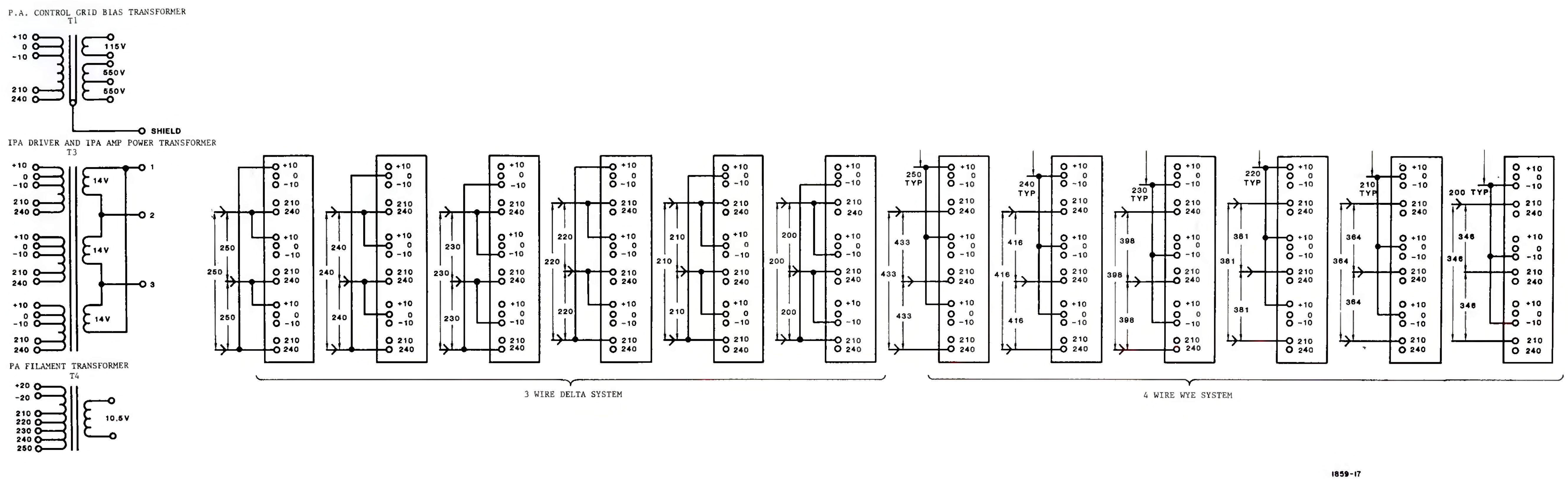


FIGURE 8-11. MAIN CABINET TRANSFORMER
WIRING DIAGRAM

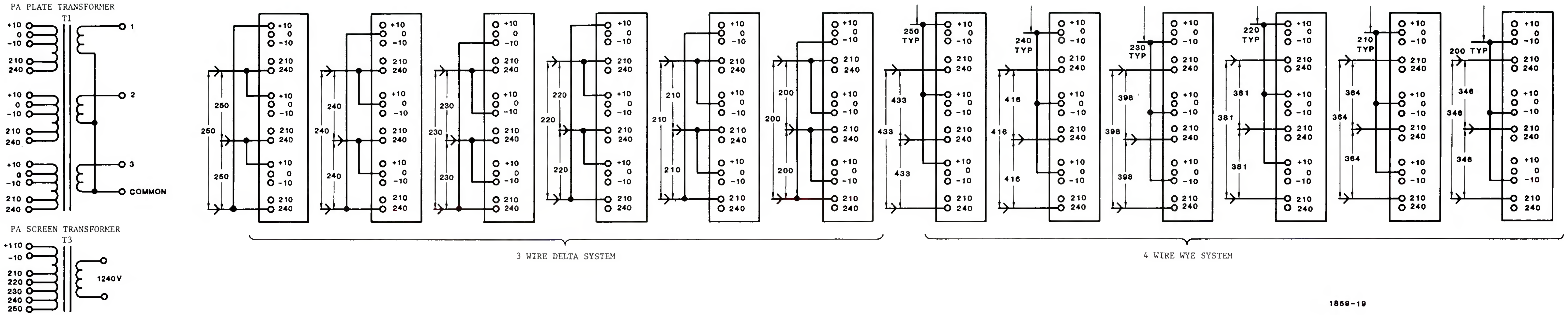


FIGURE 8-12. WIRING DIAGRAM
HIGH VOLTAGE CABINET TRANSFORMER

A

DATE 2-8-79	RUNNING SHEET		CABLE NO. 852 8777 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
1	R2		No.20 Stranded	L1	
2	R3		No.20 Stranded	C3	+
3	R3		No.20 Stranded	TB2	7
4					
5	K4	1	No.14 Stranded	T1 1	-10
6	K1	L1	No.14 Stranded	B1	L1
7	K1	L2	No.14 Stranded	B1	L2
8	K1	L3	No.14 Stranded	B1	L3
9	K2		No.16 Stranded	TB2	4
10	K2		No.16 Stranded	1A12TB2	4
11	1A12TB3	4	No.20 Stranded	Z1	-
12	1A12TB1	9	No.20 Stranded	C5	+
13	1A12TB3	1	No.20 Stranded	1A10	Fil LO
14	1A12TB3	2	No.20 Stranded	1A10	R1
15	TB2	11	No.14 Stranded	1A10	Fil LO
16	CB1	Line A	No.14 Stranded	TB1	1
17	CB1	Line B	No.14 Stranded	TB1	2
18	CB1	Load A	No.14 Stranded	K3	L1
19	CB1	Load B	No.14 Stranded	K3	L2
20	T3	S1	No.10 Stranded	CR1	AD
21	T3	S2	No.10 Stranded	CR2	AD
22	T3	S3	No.10 Stranded	CR3	AD
23	K3	T2	No.14 Stranded	T4	230V
24					
25					
26					
27	T3-PRI 1	240	No.14 Stranded	K2	T1
28	T3-PRI 2	240	No.14 Stranded	K2	T2

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 1 OF 8)
817 0591 001

A

DATE 2-8-79	RUNNING SHEET			CABLE NO. 852 8777 001	
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
29	T3-PRI 3	240	No.14 Stranded	K2	T3
30	CB4	Line A	No.14 Stranded	TB1	1
31	CB4	Line B	No.14 Stranded	TB1	2
32	CB4	Line C	No.14 Stranded	TB1	3
33	CB4	Load A	No.14 Stranded	K1	T1
34	CB4	Load B	No.14 Stranded	K1	T2
35	CB4	Load C	No.14 Stranded	K1	T3
36	S5A	Com	No.14 Stranded	T7	1
37	K4	2	No.14 Stranded	T7	4
38					
39	K4	4	No.20 Stranded	E6	
40	CB3	Line A	No.14 Stranded	TB1	1
41					
42	CB3	Line B	No.14 Stranded	TB1	2
43	TB5	4	No.20 Stranded	R33	CCW
44	K1	Coil	No.16 Stranded	1A12TB2	3
45	CB3	Line C	No.14 Stranded	TB1	3
46	CB3	Load A	No.14 Stranded	K2	L1
47	CB3	Load B	No.14 Stranded	K2	L2
48	S5A	N.O.	No.14 Stranded	T1 4	240
49	CB3	Load C	No.14 Stranded	K2	L3
50	T2	1	No.14 Stranded	T4	-20
51	T2	2	No.14 Stranded	T4	+20
52	T2	3	No.14 Stranded	K3	T1
53	CB2	Line A	No.14 Stranded	TB1	1
54	CB2	Line B	No.14 Stranded	TB1	2
55	CB2	Load A	No.14 Stranded	T5	1
56	CB2	Load B	No.14 Stranded	T5	4

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 2 OF 8)
817 0591 001

DATE 2-8-79	RUNNING SHEET		CABLE NO. 852 8777 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
57	M5	–	No.14 Stranded	TB2	10
58	M5	+	No.14 Stranded	TB2	11
59	M4	–	No.16 Stranded	E6	
60	M4	+	No.16 Stranded	R21	
61	T7	1	No.16 Stranded	1A1	P2-3
62	K4	1	No.16 Stranded	1A1	P2-10
63	E6		No.16 Stranded	1A1	P2-2
64	K3	Coil	No.16 Stranded	1A12TB2	6
65	K3	Coil	No.16 Stranded	TB2	4
66	K1	Coil	No.16 Stranded	TB2	5
67	1A12TB1	10	No.16 Stranded	TB2	3
68	K1	Coil	No.16 Stranded	TB2	3
69	TB5	5	No.20 Stranded	R33	CW
70	1A12TB2	1	No.16 Stranded	T7	5
71					
72					
73					
74					
75	T3-PRI 1	240	No.14 Stranded	T3-PRI 3	-10
76	T3-PRI 1	-10	No.14 Stranded	T3-PRI 2	240
77	T3-PRI 2	-10	No.14 Stranded	T3-PRI 3	240
78	TB5	3	No.20 Stranded	R8	Tap
79					
80					
81					
82					
83	S11	Com	No.20 Stranded	M6	+
84	T7	5	No.20 Stranded	M6	–

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 3 OF 8)
817 0591 001

DATE 2-8-79	RUNNING SHEET		CABLE NO. 852 8777 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
85	S12	REFLD,2	No.22 Stranded	P1	2
86	S12	FWD,1	No.22 Stranded	P1	17
87	T7	8	No.20 Stranded	P1	24
88					
89	Z1	–	No.20 Stranded	P1	19
90	T5	6	No.20 Stranded	P1	10
91	S3	1	No.22 Stranded	P1	8
92	S2	4	No.22 Stranded	P1	26
93	S2	1	No.22 Stranded	P1	16
94	S4	1	No.22 Stranded	P1	15
95	S1	4	No.22 Stranded	P1	34
96	S4	3	No.22 Stranded	P1	31
97	S1	1	No.22 Stranded	P1	12
98	S11	FWD,1	No.22 Stranded	P1	29
99	S11	REFLD,2	No.22 Stranded	P1	25
100	S2	2	No.20 Stranded	T5	7
101					
102	1A12TB1	4	No.16 Stranded	TB3	10
103					
104	1A12TB1	7	No.20 Stranded	TB3	13
105					
106					
107	1A12TB1	6	No.16 Stranded	TB3	12
108	1A12TB1	3	No.20 Stranded	TB3	14
109	1A12TB1	5	No.16 Stranded	TB2	2
110					
111					
112					

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 4 OF 8)
817 0591 001

DATE 2-8-79	RUNNING SHEET		CABLE NO. 852 8777 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
113					
114	1A11S2	COM	No.20 Stranded	TB3	7
115	1A11S1A	COM	No.20 Stranded	TB3	2
116	1A11S1B	COM	No.20 Stranded	TB3	3
117	1A11S1A	AUTO	No.20 Stranded	1A12TB2	10
118	1A11S1B	AUTO	No.20 Stranded	1A12TB2	8
119					
120	S9	N.O.	No.22 Stranded	P1	18
121	M3	–	No.20 Stranded	C5	–
122	S5B	NC	No.22 Stranded	P1	3
123	S5B	COM	No.22 Stranded	S9	N.O
124	S9	COM	No.22 Stranded	P1	7
125	1A1TB1	36	No.20 Stranded	1A12TB1	1
126	1A1TB1	30	No.22 Stranded	P1	32
127	C5	–	No.20 Stranded	P1	36
128	1A12TB1	2	No.22 Stranded	P1	27
129	1A12TB2	5	No.22 Stranded	P1	28
130	R31	CCW	No.20 Stranded	1A7	P3-4
131	R31	TAP	No.20 Stranded	1A7	P3-3
132	R31	CW	No.20 Stranded	1A7	P3-2
133	TB3	6	No.22 Stranded	P1	11
134	K4	3	No.22 Stranded	P1	4
135	TB3	5	No.22 Stranded	P1	13
136	K4	3	No.20 Stranded	1A12TB2	2
137	1A12TB2	7	No.22 Stranded	P1	35
138	1A12TB2	9	No.22 Stranded	P1	30
139	1A1TB1	35	No.22 Stranded	P1	6
140	1A12TB1	8	No.20 Stranded	P1	20

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 5 OF 8)
817 0591 001

DATE 2-8-79	RUNNING SHEET		CABLE NO. 852 8777 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
141	R2		No.20 Stranded	R8	CW
142	C2	–	No.20 Stranded	R8	TAP
143	R3		No.20 Stranded	R8	CCW
144	M1		No.20 Stranded	T2	3
145	M1		No.20 Stranded	T4	230V
146	R32		No.20 Stranded	C4	+
147	C4	–	No.20 Stranded	TJ2	
148					
149					
150					
151					
152	S10A	4	No.20 Stranded	E5	
153	S10B	3	No.20 Stranded	TB2	9
154	S10A	1	No.20 Stranded	1A12TB3	3
155	S10B	1	No.20 Stranded	1A12TB3	5
156					
157	S10B	5	No.20 Stranded	TB3	8
158	S10A	2	No.20 Stranded	E6	
159					
160					
161			4 Cond. Audio		
Red	1A11R2	TAP		P1	1
Blk	1A11R3	TAP		P1	5
Grn	1A11R5	TAP		P1	21
Wht	1A11R4	TAP		P1	33
Shld		Bus Wire		P1	14
162					
163					

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 6 OF 8)
817 0591 001

DATE 2-8-79	RUNNING SHEET			CABLE NO. 852 8777 001	
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
164					
165 Red	TB3	1	2 Cond. Audio	P1	23
Blk	TB2	14		P1	9
Shld				P1	22
166					
167 Ctk	1A11R4	CW	Coax	DC2	FWD
Shld		Bus Wire			
168 CTR	1A11R5	CW	Coax	DC2	REFLD
Shld		Bus Wire			
169 Red	1A11R2	CW		1A13	FWD
Blk	1A11R3	CW		1A13	REFLD
Shld	Buss Wire			1A13	Gnd
170					
171					
CTR	E3		Coax RG 58	1A10	E2
Shld	E1			1A10	Gnd
172					
173					
174					
175					
176					
177					
178					
179					
180	Z2,Z3	AD	No.20 Stranded	L1	
181	Z2	CATH	No.20 Stranded	TB2	6
182	Z3	CATH	No.20 Stranded	TB2	8
183					

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 7 OF 8)
817 0591 001

DATE 2-8-79 | RUNNING SHEET | CABLE NO. 852 8777 001

WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
184					
185					
186					
187					
188	TB3	7	No.16 Stranded	TB2	2
189	TB3	4	No.16 Stranded	E6	
190	TB2	12	No.14 Stranded	TB3	9
191	TB3	11	No.16 Stranded	TB2	5
192					
193					
194					
195	R33	Tap	No.20 Stranded	1A10	E3
196					
197	T2		No.20 Stranded	TB5	1
198	T2		No.20 Stranded	TB5	2

FIGURE 8-13. WIRE LIST
MAIN TRANSMITTER CABINET
(SHEET 8 OF 8)
817 0591 001

DATE	RUNNING SHEET		CABLE NO. 852 8767 001			C

WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
1	T2	4	No.14 Stranded	T3	−10
2	K4	T1	No.14 Stranded	R1	
3	K4	T2	No.14 Stranded	R2	
4	K4	T3	No.14 Stranded	R3	
5	T2	1	No.14 Stranded	T3	+110
6	K4	L3	No.14 Stranded	K3	T1
7	K4	L2	No.14 Stranded	K3	T2
8	K4	L1	No.14 Stranded	K3	T3
9	CB2	Line	No.14 Stranded	K3	L2
10	CB2	Load	No.14 Stranded	B1	1
11	K3	L1	No.14 Stranded	B1	2
12	K3	L1	No.14 Stranded	CB1	Line A
13	CB1	Load A	No.14 Stranded	T3	230
14	K3	L2	No.14 Stranded	CB1	Line B
15	CB1	Load B	No.14 Stranded	T2	3
16	K3	1	No.20 Stranded	TB1	13
17	K3	2	No.20 Stranded	TB1	14
18	K3		No.20 Stranded	K4	
19	K3		No.20 Stranded	K4	L4
20	K4	T4	No.20 Stranded	S5B	NC
21	K4		No.20 Stranded	TB1	10
22	S2A	N.O.	No.20 Stranded	S10	L2
23	S4A	N.O.	No.20 Stranded	S5A	N.O.
24	K1		No.20 Stranded	S5A	Com
25	K1		No.20 Stranded	K2	
26	K2		No.20 Stranded	TB1	Com
27	S1A	N.O.	No.20 Stranded	S4A	Com
28	S1A	Com	No.20 Stranded	S3A	Com

FIGURE 8-14. WIRE LIST
HIGH VOLTAGE POWER SUPPLY
(SHEET 1 OF 2)
817 0548 001

WARNING: Disconnect primary power prior to servicing.

DATE	RUNNING SHEET		CABLE NO. 852 8767 001		
WIRE NO.	FROM		WIRE SIZE AND TYPE	TO	
	EQUIPMENT	TERMINAL		EQUIPMENT	TERMINAL
29	S3A	N.O.	No.20 Stranded	S2A	Com
30	K3		No.20 Stranded	TB1	12
31	S2A	N.O.	No.20 Stranded	K4	
32	C6		No.14 Stranded	TB1	9
33	Z8	2	No.20 Stranded	TB1	8
34	TB1	7	No.20 Stranded	S4B	N.C.
35	S10	L2	No.20 Stranded	S1B	N.C.
36	S1B	N.C.	No.20 Stranded	S4B	N.C.
37	S4B	Com	No.20 Stranded	S1B	Com
38	S1B	Com	No.20 Stranded	TB1	6
39	S5B	Com	No.20 Stranded	S4B	Com
40	TB1	3	No.20 Stranded	TB3	3
41	TB1	2	No.20 Stranded	TB3	2
42	TB1	1	No.20 Stranded	Z8	3
43	Z8	5	No.20 Stranded	TB1	5
44	TB3	1	No.20 Stranded	K2	
45	R16		No.20 Stranded	Z8	5
46	R11		No.16 Stranded	Z8	4
47	Z8	6	No.16 Stranded	TB1	4
48	S5B	N.C.	No.20 Stranded	TB1	7
49			—		
50	TB1	6	No.20 Stranded	S3B	Comm.
51	S3B	Comm	No.20 Stranded	S2B	Comm
52	TB1	7	No.20 Stranded	S3B	N.C.
53	S3B	N.C.	No.20 Stranded	S2B	N.C.

FIGURE 8-14. WIRE LIST
HIGH VOLTAGE POWER SUPPLY
(SHEET 2 OF 2)
817 0548 001

WARNING: Disconnect primary power prior to servicing.

APPENDIX A

MANUFACTURERS DATA

APPENDIX A

MANUFACTURERS DATA

A-1. INTRODUCTION

A-2. This appendix consists of the following technical data which identifies operating characteristics and parameters for various replaceable items used throughout the FM-25K circuitry.

a. Technical Data Sheet, Eimac 8990 Tetrode

b. Engineering Newsletter, Eimac WHM65D69

c. Technical Data Sheet, Teledyne Series 611 Solid-State Relay

d. Engineering Bulletin H2, DuPont Kapton Physical Properties

e. Engineering Bulletin H4, DuPont Kapton Electrical Properties

f. Application Note AN-778, Mounting Techniques for Power Semiconductors

g. Technical Data Sheet, CD 2315 RF Power Transistor

h. Technical Data Sheet, Lincoln Blower Motor 145T

i. Technical Data Sheet, Dwyer Series 1800 Air Flow Switch

j. Technical Data Sheet, Allen-Bradley 810 Inverse Time Current Relay

k. Semiconductor Base Diagrams 1859-41

l. Engineering Report, Susceptibility of the Open-Delta Connection to Third Harmonic and Transient Disturbances

m. Telemecanique, Magnetic Starters

n. Telemecanique, Overload Relays

o. HARRIS CORPORATION, Broadcast Products Division

8 9 9 0
(formerly X-2213)

VHF
RADIAL BEAM
POWER TETRODE

TECHNICAL DATA

The EIMAC 8990 is a ceramic/metal power tetrode intended for use in audio or radio frequency applications. It features a type of internal mechanical structure which results in high rf operating efficiency. Low rf losses in this structure permit operation at full ratings up to 110 MHz.

The 8990 has a gain of over 18 dB in FM broadcast service, and is also recommended for radio-frequency linear power amplifier service, and for VHF television linear amplifier service. The anode is rated for 20 kW of dissipation with forced-air cooling and incorporates a highly efficient cooler of new design.

GENERAL CHARACTERISTICS[1]

ELECTRICAL

Filament: Thoriated Tungsten	
Voltage	10.0 ± 0.5 V
Current, at 10.0 volts	140 A
Amplification Factor, average	
Grid to Screen	6.7
Direct Interelectrode Capacitances (cathode grounded):	
Cin	190 pF
Cout	23.5 pF
Cgp	1.5 pF
Direct Interelectrode Capacitances (grid and screen grounded):	
Cin	83 pF
Cout	24.5 pF
Cpk	0.2 pF
Frequency of Maximum Ratings (CW)	110 MHz

1 Characteristics & operating values are based on calculations and measured data. These figures may change without notice as a result of data or product refinement. EIMAC Div. of Varian should be consulted before using this information for final equipment design.

MECHANICAL

Maximum Overall Dimensions:	
Length	9.500 In.
Diameter	8.800 In.
Net Weight (Approximate)	14.0 Lbs
Operating Position	Axis vertical, base up or down
Cooling	Forced air
Operating Temperature, maximum	
Ceramic/Metal Seals and Anode Core	250°C
Base	Special, concentric
Recommended Air System Socket	SK-320
Recommended Air Chimney	SK-326

(Effective 4 May 1978)

RADIO FREQUENCY POWER AMPLIFIER OR OSCILLATOR

Class C Telegraphy or FM

(Key-Down Conditions)

ABSOLUTE MAXIMUM RATINGS

DC PLATE VOLTAGE	10,000	VOLTS
DC SCREEN VOLTAGE	2000	VOLTS
DC PLATE CURRENT	5.0	AMPERES
PLATE DISSIPATION	20,000	WATTS
SCREEN DISSIPATION	450	WATTS
GRID DISSIPATION	200	WATTS

TYPICAL OPERATION (frequencies to 30 MHz)

Plate Voltage	7.5	9.0	kVdc
Screen Voltage	750	900	Vdc
Grid Voltage	-200	-250	Vdc
Plate Current	3.68	4.01	Adc
Screen Current [1]	208	222	mAdc
Grid Current [1]	91	88	mAdc
Peak rf Grid Voltage [1]	265	300	v
Calculated Drive Power	24.1	26.4	W
Plate Dissipation [1]	5.84	7.93	kW
Plate Output Power [1]	21.8	28.2	kW
Load Impedance	1062	1136	Ω

1 Approximate value

TYPICAL OPERATION, COMMERCIAL FM SERVICE (measured values at frequency shown, in EIMAC cavity amplifier)

Frequency of Operation	88.3	107.7	MHz
Plate Voltage	9.0	9.0	kVdc
Screen Voltage	800	800	Vdc
Grid Voltage	-400	-300	Vdc
Plate Current	4.08	4.15	Adc
Screen Current	200	200	mAdc
Grid Current	40	38	mAdc
Drive Power	325	360	W
Useful Power Output [1]	28.75	28.9	kW
Efficiency	80.5	77.4	%
Gain	19.5	19.0	dB

1 Delivered to the load

APPLICATION

MOUNTING - The 8990 must be operated with its axis vertical. The base of the tube may be up or down at the convenience of the circuit designer.

SOCKET & CHIMNEY - The EIMAC air-system socket SK-320 and air chimney SK-326 are designed especially for use with the 8990. The use of the recommended air flow through this socket provides effective forced-air cooling of the base, with air then guided through the anode cooling fins by the air chimney.

COOLING - The maximum temperature rating for the external surfaces of the tube is 250°C, and sufficient forced-air cooling must be used in all applications to keep the temperature of the anode (at the base of the cooling fins) and the temperature of the ceramic/metal seals comfortably below the rated maximum.

The cooling characteristics of the anode are shown in the attached graph, for power levels from 7.5 kW to 20 kW dissipation. The designer is cautioned to keep in mind that this is ABSOLUTE data, with pure dc power, with no safety factors added, and the pressure drop figures make no allowance for losses in filters, ducting, and the like.

It is considered good engineering practice to design for a maximum anode core temperature of 225°C, and temperature sensitive paints are available for checking base and seal temperatures before any design is finalized. It is also considered good practice to add a 15% safety factor to the indicated airflow, and allow for variables such as dirty air filters, rf seal heating at VHF, and the fact that the anode cooling fins may not be clean if the tube has been in service for some length of time. Special cooling is required in the center of the stem (base), by means of special directors or some other provision. An air interlock system should be incorporated into the design to automatically remove all voltages from the tube in case of even partial failure of the tube cooling air.

Air flow must be applied before or simultaneously with the application of power, including the tube filament, and should normally be maintained for a short period of time after all power is removed to allow for tube cooldown.

FILAMENT OPERATION - The rated nominal filament voltage for the 8990 is 10.0 volts, as measured at the socket or tube base. Variation in voltage should be maintained within plus or minus five percent. During application of filament voltage the inrush current should be limited to no more than twice normal current.

The peak emission capability at nominal filament voltage is normally more than that required for communication service. A small decrease in filament temperature due to reduction in filament voltage can increase tube life by a substantial percentage. It is good practice to determine the nominal filament voltage for a particular application that will not adversely effect equipment operation. This is done by measuring some important parameter of performance (such as plate current, power output, or distortion) while filament voltage is reduced. At some point in filament voltage there will be a noticeable change in the operating parameter being monitored, and the operating filament voltage must be slightly higher than the level at which deterioration was noted. When filament voltage is to be reduced in this manner it should be regulated and held to plus or minus one percent, and the actual operating value should be checked periodically to maintain proper operation.

ELECTRODE DISSIPATION RATINGS - The maximum dissipation ratings for the 8990 must be respected to avoid damage to the tube. An exception is the plate dissipation which may be permitted to rise above the rated maximum during brief periods, such as may occur during tuning.

GRID OPERATION - The 8990 control grid has a maximum dissipation rating of 200 watts. Precautions should be observed to avoid exceeding this rating. The grid bias and driving power should normally be kept near the values shown in the TYPICAL OPERATION section of the data sheet whenever possible.

SCREEN OPERATION - The power dissipated by the screen of the 8990 must not exceed 450 watts. Screen dissipation, in cases where there is no ac applied to the screen, is the simple product of the screen voltage and the screen current. If the screen voltage is modulated, the screen dissipation will depend upon loading, driving power, and carrier screen voltage.

Screen dissipation is likely to rise to excessive values when the plate voltage, bias voltage, or plate load are removed with the filament and screen voltages applied. Suitable protective means must be provided to limit the screen dissipation to 450 watts in the event of circuit failure. Energy limiting circuitry (which will activate if there is a fault condition) and spark gap over-voltage protection are recommended as good engineering practice.

The 8990 may exhibit reversed (negative) screen current under some operating conditions. The screen supply voltage must be maintained constant for any values of negative and positive screen current which may be encountered. Dangerously high plate current may flow if the screen power supply exhibits a rising voltage characteristic with negative screen current. Stabilization may be accomplished with a bleeder resistor connected from screen to cathode, and this is absolutely essential if a series electronic regulator is employed.

FAULT PROTECTION - In addition to normal plate overcurrent interlock and screen current interlock it is good practice to protect the tube from internal damage which could result from a plate arc at high voltage. In all cases some protective resistance, 10 to 50 ohms, should be used in series with the tube anode to absorb power supply stored energy in case a tube arc should occur. If power supply stored energy is high some form of electronic crowbar which will discharge power supply capacitors in a few microseconds following indication of start of a tube arc is recommended.

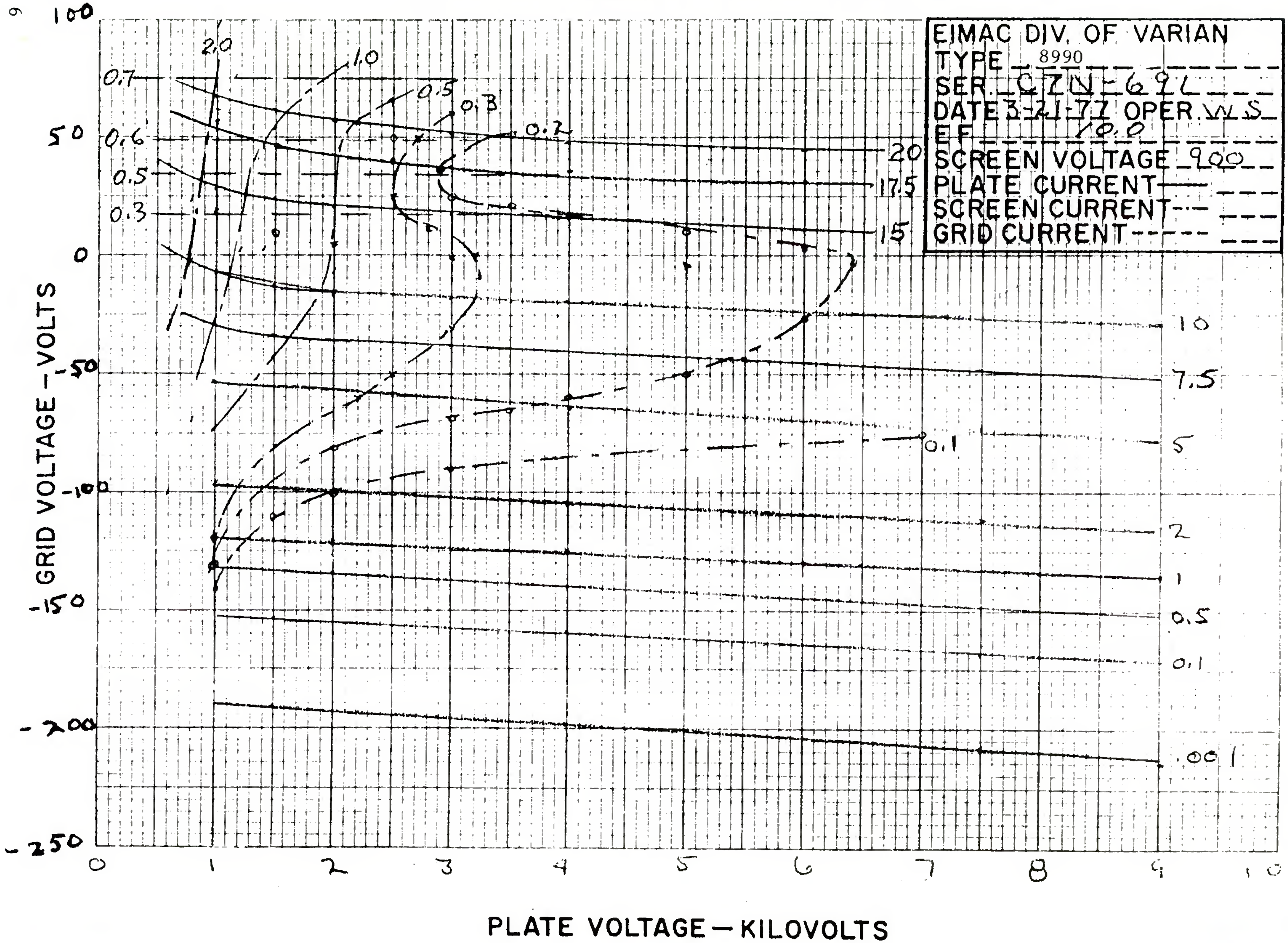
HIGH VOLTAGE - Normal operating voltages used with the 8990 are deadly and the equipment must be designed properly and operating precautions must be followed. All equipment must be designed so that no one can come into contact with high voltages. All equipment must include safety enclosures for high-voltage circuits and terminals, with interlock switches to open primary circuits of the power supply and to discharge high-voltage capacitors whenever access doors are opened. Interlock switches must not be bypassed or "cheated" to allow operation with access doors open. Always remember that HIGH VOLTAGE CAN KILL.

INTERELECTRODE CAPACITANCE - The actual internal interelectrode capacitance of a tube is influenced by many variables in most applications, such as stray capacitance to the chassis, capacitance added by the socket used, stray capacitance between tube terminals, and wiring effects. To control the actual capacitance values within the tube, as the key component involved, the industry and Military Services use a standard test procedure as described in Electronic Industries Association Standard RS-191. This requires the use of specially constructed test fixtures which effectively shield all external tube leads from each other and eliminate any capacitance reading to "ground". The test is performed on a cold tube. Other factors being equal, controlling internal tube capacitance in this way normally assures good interchangeability of tubes over a period of time, even when the tube may be made by different manufacturers. The capacitance values shown in the manufacturer's technical data, or test specifications, normally are taken in accordance with Standard RS-191.

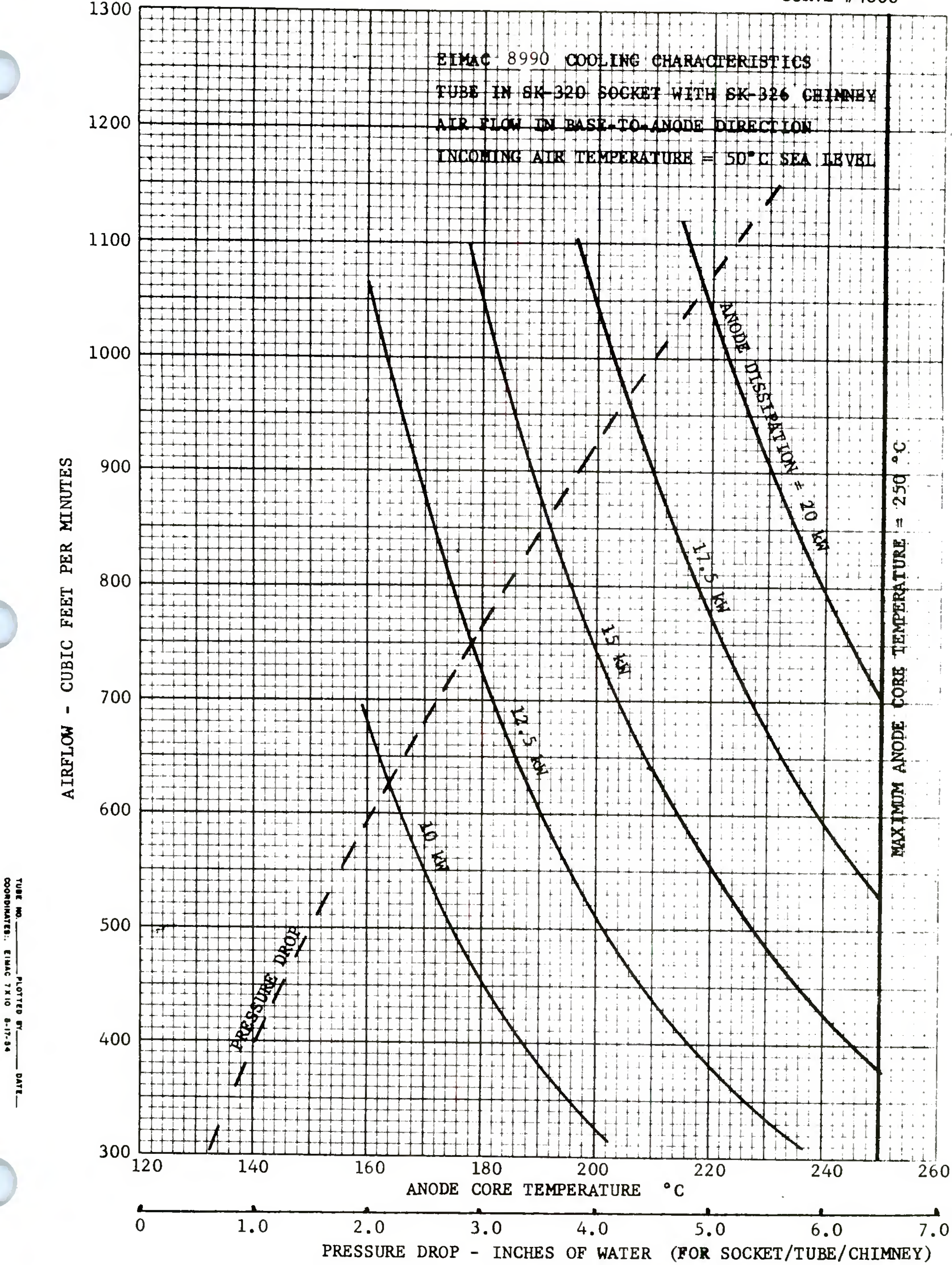
The equipment designer is therefore cautioned to make allowance for the actual capacitance values which will exist in any normal application. Measurements should be taken with the socket and mounting which represent approximate final layout if capacitance values are highly significant in the design.

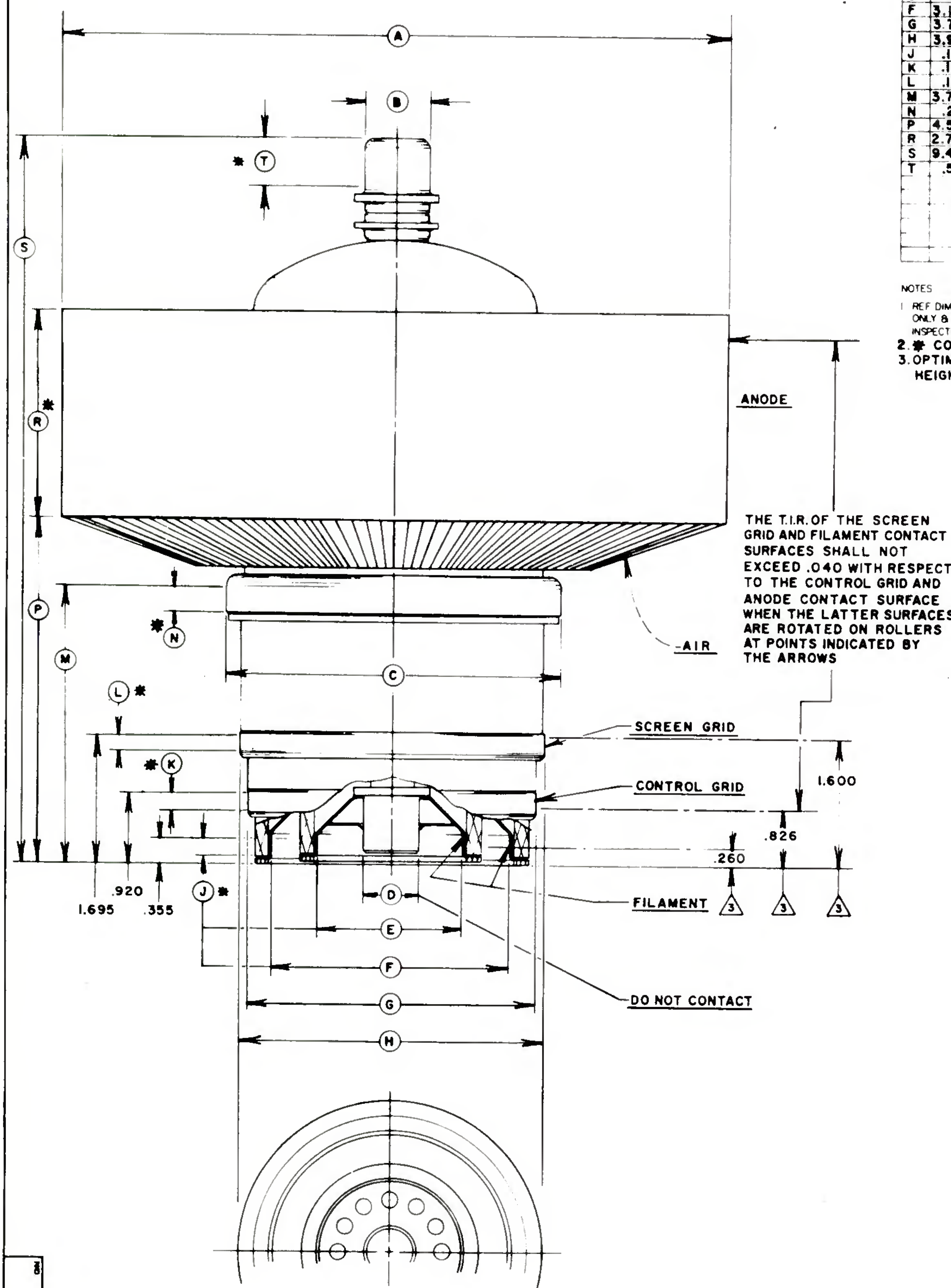
SPECIAL APPLICATIONS - If it is desired to operate this tube under conditions widely different from those listed here, write to Application Engineering, Power Grid Tube Division, EIMAC Division of Varian, 301 Industrial Way, San Carlos, CA 94070 for recommendations.

GROUNDED CATHODE
CONSTANT CURRENT CHARACTERISTICS



CURVE #4800


EIMAC 8990 COOLING CHARACTERISTICS
TUBE IN SK-320 SOCKET WITH SK-326 CHIMNEY
AIR FLOW IN BASE-TO-ANODE DIRECTION
INCOMING AIR TEMPERATURE = 50°C SEA LEVEL
AIRFLOW - CUBIC FEET PER MINUTES
1300
1200
1100
1000
900
800
700
600
500
400
300
ANODE DISSIPATION = 20 KW
17.5 KW
15 KW
12.5 KW
10 KW
PRESSURE DROP
MAXIMUM ANODE CORE TEMPERATURE = 250 °C
120
140
160
180
200
220
240
260
ANODE CORE TEMPERATURE °C
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
PRESSURE DROP - INCHES OF WATER (FOR SOCKET/TUBE/CHIMNEY)
TUBE NO.______ PLOTTED BY______ DATE__
COORDINATES: EIMAC 7 X 10 8-17-84



DIMENSIONAL DATA

DIM	INCHES MIN.	INCHES MAX.	INCHES REF.	MILLIMETERS MIN.	MILLIMETERS MAX.	MILLIMETERS REF.
A	8.670	8.800				
B	.855	.895				
C	4.406	4.468				
D	.600	.760				
E	1.896	1.936				
F	3.133	3.173				
G	3.792	3.832				
H	3.980	4.020				
J	.188					
K	.188					
L	.188					
M	3.718	3.781				
N	.219					
P	4.593	4.656				
R	2.705	2.825				
S	9.465	9.840				
T	.500					

NOTES

1. REF DIMENSIONS ARE FOR INFO ONLY & ARE NOT REQUIRED FOR INSPECTION PURPOSES
2. * CONTACT SURFACE.
3. OPTIMUM FILAMENT & GRID CONNECTOR HEIGHTS FOR SOCKET DESIGN PURPOSES.

LTR	DESCRIPTION OF CHANGE	DATE	BY
A	DIM A WAS 8.770 – 8.900, S WAS 2.272 – 2.648	3-1-77	D.H.
B	DIM. V WAS 2.330 – 2.450	4-25-77	D.H.
C	REVISED DIM. AND SYMBOLS	5-4-77	D.H.
D	DIM. S WAS 9.125 - 9.500	8-26-77	D.H.

DRAWN D.H. 4 JAN 77 ENGR APPR. 1-13-77 SCALE NONE

CHK'D SUPERSEDES

EIMAC, division of varian
San Carlos, California

CODE IDENT No.

PART No.

OUTLINE 8990

No. 169084 D

169084

LIFE VS. FILAMENT VOLTAGE

TUBE TYPES WITH THORIATED-TUNGSTEN FILAMENTS OR CATHODES.

Power tube users and equipment manufacturers are naturally interested in extending the life of these tubes. A very large factor in tube life is the temperature of the thoriated-tungsten cathode.

The equipment manufacturer and the end user of the equipment have more control over tube life through proper adjustment of filament voltage (filament power) than is generally realized. This is true because tube ratings and most equipment designs are conservative in peak cathode emission required of the tube compared with peak cathode emission available at nominal rated filament voltage.

It is good practice to determine in the field for each particular combination of equipment and operating power level, the nominal filament voltage for best life. This is best done in the field by measuring some important parameter of performance such as plate current, power output, or distortion while filament voltage on the power tube is reduced. At some point in filament voltage there will be a noticeable reduction in plate current, or power output, or an increase in distortion. Operation may safely be at a filament voltage slightly higher than that point at which performance appeared to deteriorate. A recheck should be made in 12 to 24 hours to make certain that emission is stable.

The thoriated-tungsten filament or cathode is processed in a hydrocarbon atmosphere to form a deep layer of di-tungsten carbide on the surface. Stable emission is not possible without the carbide. If the carbide layer is too deep the filament becomes too brittle to withstand shipping and handling. The end of useful life for this type of filament occurs when most of the carbon has evaporated or combined with residual gas, depleting the carbide surface layer.

Theoretically it is estimated that a 3% increase in filament voltage will result in a 20°K increase in temperature, a 20% increase in peak emission, and a 50% decrease in life due to carbon loss. This, of course, works the other way, too. For a small decrease in temperature and peak emission, life of the carbide layer and hence tube life can be increased by a substantial percentage. Peak emission as meant here is the emission obtained in the test for emission described in the Test Specification. This is normally many times the peak emission required in communication service.

Continued......

Obviously, if small percentage variations in filament voltage are to have a large percentage effect on tube life, it is important to be able to measure and adjust filament voltage measured at the tube terminals with accuracy of about 1%.

The common rectifier type of multimeter which is used for almost every measurement in electronic gear, should not be relied on for AC filament voltage measurement. A simple iron-vane AC meter which has recently been checked against a reliable standard is the best inexpensive instrument for this measurement because it responds to the RMS, or heating value, of the voltage wave form.

As a guide for use with most communications, and broadcast equipment, to get the best life service from your EIMAC power tubes, the following table has been prepared. It is not meant to imply that lower filament voltage will not be satisfactory in some instances.

SUGGESTED NOMINAL FILAMENT VOLTAGE

FOR

EXTENDED LIFE IN BROADCAST AND COMMUNICATION SERVICE

TUBE TYPE	
3X2500A3 and F3	7.2 volts
3X3000A1 and A7	7.2
3CX2500A3 and F3	7.2
3CX3000A1 and A7	7.2
3CX10,000A3, A1 and A7	7.2
3CX15,000A3	6.0
6697A	12.3
4-125A	4.8
4-400A	4.8
4-1000A	7.2
4W20,000A	(2300 watts cathode heating power)
4CX3000A	8.6 volts
4CX5000A	7.2
4CX10,000D	7.2
4CX15,000A	6.0
4CX35,000C	9.0
4CV100,000C	9.0
4E27A	4.8
5-500A	9.5
5CX1500A	4.8
5CX3000A	8.6

Credit is due the paper, High Power Transmitting Valves ---, by Walker, Aldous, Roach, Webb and Goodchild, IEE Paper No. 3200E March, 1960, also the paper Life Expectancy Tubes ---, Eitel-McCullough, October 6, 1963, by Paul Williams.

TELEDYNE RELAYS

611

AC INPUT

SOLID STATE AC RELAY

OPTICALLY ISOLATED
ZERO VOLTAGE TURN-ON

FEATURES

- All solid state
- Optical isolation between control and load circuits
- Zero-voltage turn-on, zero current turn-off
- High dv/dt rating (200 V/μsec typical)
- Multipurpose terminals – screws & quick disconnects
- High surge rating (1000% overload)
- High transient peak voltage (up to 600 V)

APPLICATIONS

- Computer Peripherals
- Machine Tool Controls
- Process Control Systems
- Traffic Control Systems

RELIABLE SOLID STATE SWITCHING OF

- Solenoids
- Motor Starters
- Motors
- Lamp Loads
- Transformers
- Heaters

PART NUMBERING

INPUT CONTROL VOLTAGE RANGE	OUTPUT VOLTAGE RATING (VAC)		OUTPUT (LOAD) CURRENT RATING & PART NUMBERS			
	Continuous (RMS)	Transient (PEAK)	10 AMP	15 AMP	25 AMP	40 AMP
90-250 VAC	140	200	611-17	611-13	611-11	611-15
	250	400	611-18	611-14	611-12	611-16
	250	600	611-18H	611-14H	611-12H	611-16H

ELECTRICAL SPECIFICATIONS

(25°C UNLESS OTHERWISE SPECIFIED)

INPUT (CONTROL) SPECIFICATIONS	MIN.	TYP.	MAX.	UNITS
CONTROL VOLTAGE RANGE	90		250	VAC
FREQUENCY RANGE	47		70	Hz
INPUT CURRENT AT MAX. CONTROL VOLTAGE (-40°C ≤ Ta ≤ 80°C)			18	MA (RMS)
TURN-ON VOLTAGE (-40°C ≤ Ta ≤ 80°C)	90			VAC
TURN-OFF VOLTAGE (-40°C ≤ Ta 80°C)			4	VAC
ISOLATION (INPUT TO OUTPUT, INPUT TO CASE, OUTPUT TO CASE)	10^9			OHMS
CAPACITANCE (INPUT TO OUTPUT)		8	10	pf
DIELECTRIC STRENGTH (INPUT TO OUTPUT, INPUT TO CASE, OUTPUT TO CASE)	1500			VAC (RMS) 60 Hz

PATENT #3,648,075

OUTPUT (LOAD) SPECIFICATIONS		MIN.	TYP.	MAX.	UNITS
OUTPUT CURRENT RATING (SEE FIGURE 2 & 4)		0.05		10,15 25, 40	AMPS (RMS)
LOAD VOLTAGE RATING (SEE PART NUMBERING)		12		140, 250	VAC (RMS)
FREQUENCY RANGE		47		70	Hz
SURGE CURRENT RATING (16MS) (SEE FIGURE 3)				1000	% OF RATING
OVER VOLTAGE RATING	611-11, -13, -15, -17	200			V PEAK
	611-12, -14, -16, -18	400			
	611-12H, -14H, -16H, -18H	600			
CONTACT VOLTAGE DROP AT RATED CURRENT			0.8	1.5	VAC
TURN-ON TIME (60 Hz)				10	MS
TURN-OFF TIME (60 Hz)			16	40	MS
OFF-STATE LEAKAGE (40°C ≤ Ta ≤ 80°C)	@ 140 V			8	MA (RMS)
	@ 250 V			13	
ZERO VOLTAGE TURN-ON POINT			±12		V (PEAK)
OFF-STATE dv/dt (SEE NOTE 1)		100	200		V/μsec
TRIAC POWER DISSIPATION	10A, 15A, 25A			1.21	WATTS/ AMP
	40A			1.25	
TRIAC JUNCTION TEMPERATURE	10, 15, 25A			100	DEGREES CENTIGRADE
	40A			110	
THERMAL RESISTANCE, JUNCTION TO BASE (Θ_{J-B}) (SEE FIGURE 2 AND 3)	10A			3.1	°C/ WATT
	15			1.8	
	25A, 40A			1.3	

Specifications shown herein are subject to change without notice.

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CHARACTERISTIC CURVES

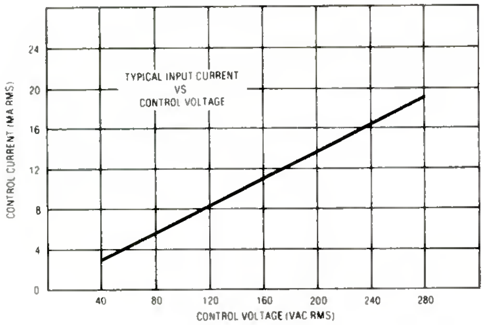


FIGURE 1

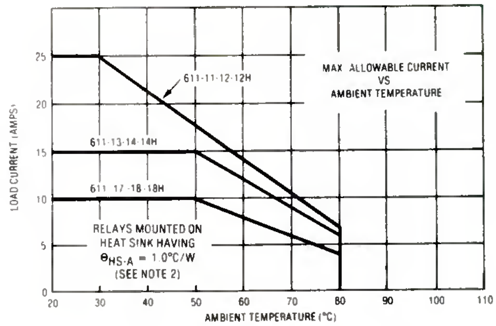


FIGURE 2

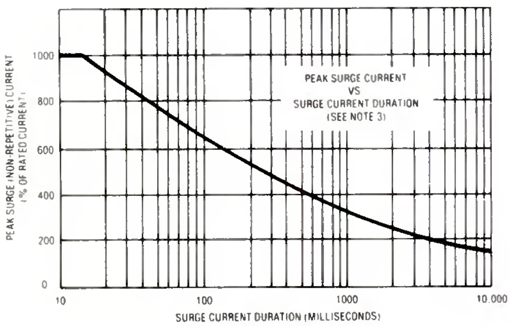


FIGURE 3

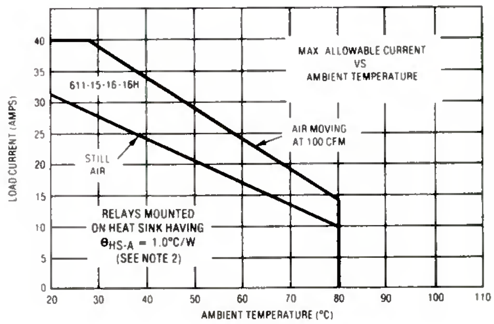
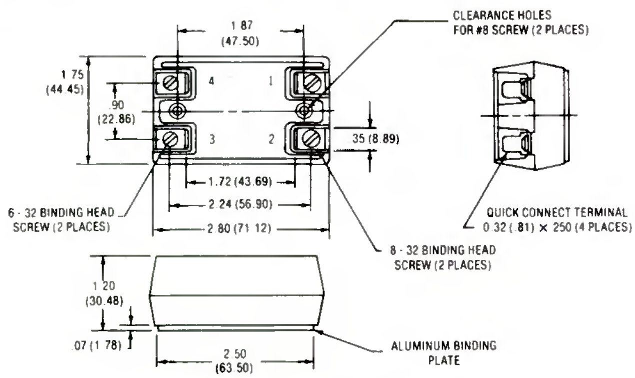
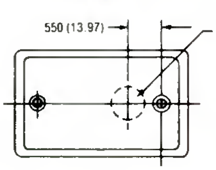


FIGURE 4

MECHANICAL SPECIFICATIONS

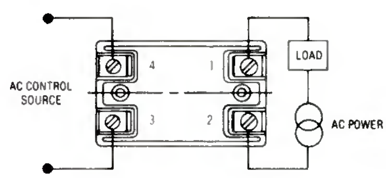




AMBIENT TEMPERATURE RANGE:
–40°C to +80°C OPERATING
–40°C to +100°C STORAGE
WEIGHT: 4 OZ. MAX.
CASE MATERIAL: GLASS FILLED POLYCARBONATE
RATED SELF-EXTINGUISHING
BASE PLATE MATERIAL: ALUMINUM

DIMENSIONS ARE SHOWN IN INCHES (MILLIMETERS)

WIRING DIAGRAM



NOTES:

1. Output (dv/dt) protection is provided in all models, and they are designed to operate resistive or inductive loads.
2. A typical 1.0°C/W heat sink is Astrodyne P/N 2518-0500-A00B.
3. Triac may lose blocking capability during and after surge until Tj falls below maximum.

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ELECTRICAL INSULATION PRODUCTS DIVISION
DU PONT FILM DEPARTMENT

BULLETIN H-2

PHYSICAL-THERMAL

"KAPTON" POLYIMIDE FILM PHYSICAL - THERMAL PROPERTIES

Kapton* polyimide films retain their physical properties over a wide temperature range. They have been used in field applications where the environmental temperatures have been as low as −269°C. and as high as 400°C. Unfortunately, complete data are not available at these extreme conditions because of the difficulty of maintaining test equipment at these temperatures. Therefore, the majority of our technical data falls in the −195°C. to 200°C. range which is summarized in Table 1.

TABLE 1

TYPICAL PHYSICAL AND THERMAL PROPERTIES OF "KAPTON" POLYIMIDE FILM (Type H Film 1 mil)

PHYSICAL PROPERTIES		TYPICAL VALUES			TEST METHOD
		—195°C	25°C	200°C	
Ultimate Tensile Strength	(MD)	35,000 psi	25,000 psi	17,000 psi	ASTM D-882-64T
Yield Point	(MD)		10,000 psi at 3%	6,000 psi at 3%	ASTM D-882-64T
Stress to Produce 5% Elongation	(MD)		13,000 psi	8,500 psi	ASTM D-882-64T
Ultimate Elongation	(MD)	2%	70%	90%	ASTM D-882-64T
Tensile Modulus	(MD)	510,000 psi	430,000 psi	260,000 psi	ASTM D-882-64T
Impact Strength			6 Kg-cm/mil		Du Pont Pneumatic Impact Test
Folding Endurance (MIT)			10,000 cycles		ASTM D-2176-63T
Tear Strength—Propagating (Elmendorf)			8 gm/mil		ASTM D-1922-61T
Tear Strength—Initial (Graves)			510 gm/mil		ASTM D-1004-61
Bursting Test (Mullen)			75 psi		ASTM D-774-63T
Density			1.42 gm/cc		ASTM D1505-63T
Coefficient of Friction Kinetic (Film-to-Film)			.42		ASTM D-1894-63
Refractive Index (Becke Line)			1.78		Encyclopaedic Dictionary of Physics, Volume I

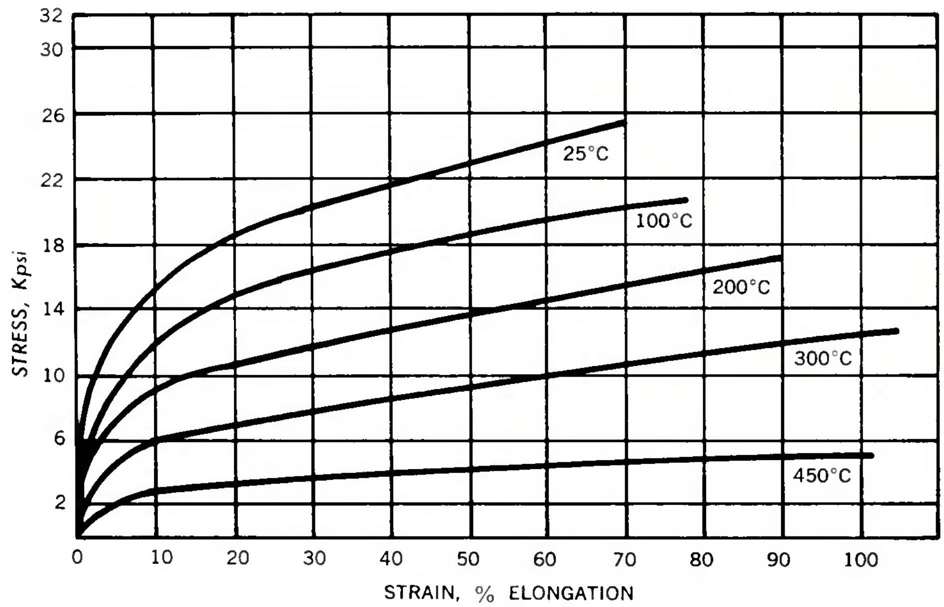
THERMAL PROPERTIES	TYPICAL VALUES	TEST CONDITION	TEST METHOD
Melting Point	NONE		
Zero Strength Temperature	815°C	20 psi load for 5 seconds	Hot Bar (Du Pont Test)
Coefficient of Linear Expansion	2.0×10^{-5} in./in./°C	(—) 14°C to 38°C	ASTM D-696-44
Coefficient of Thermal Conductivity	3.72×10^{-4} $\frac{\text{(cal) (cm)}}{\text{(cm}^2\text{) (sec) (°C)}}$	25°C	Model TC-1000 Twin Heatmaster Comparative Tester
	3.89×10^{-4} "	75°C	
	4.26×10^{-4} "	200°C	
	4.51×10^{-4} "	300°C	
Specific Heat	.261	cals/gm/°C	Differential Calorimetry
Flammability	Self-extinguishing when flame removed		
Heat Sealable	No		

* Reg. U.S. Pat. Off.

MECHANICAL PROPERTIES

The usual values of tensile strength, tensile modulus, and ultimate elongation at various temperatures can be obtained from the typical stress-strain curves shown below. Such properties as tensile strength and modulus have an inverse relation with temperature, while elongation peaks to a maximum value at about 300°C. Other factors such as humidity, film thickness, and Instron elongation rate were found to have only a negligible effect on the shape of the 25°C. curve.

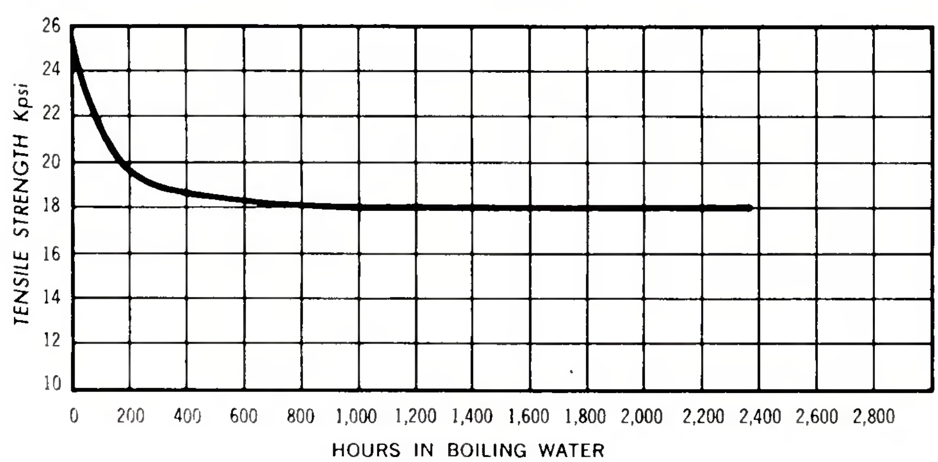
TENSILE STRESS STRAIN CURVES
(Type H Film 1 mil)



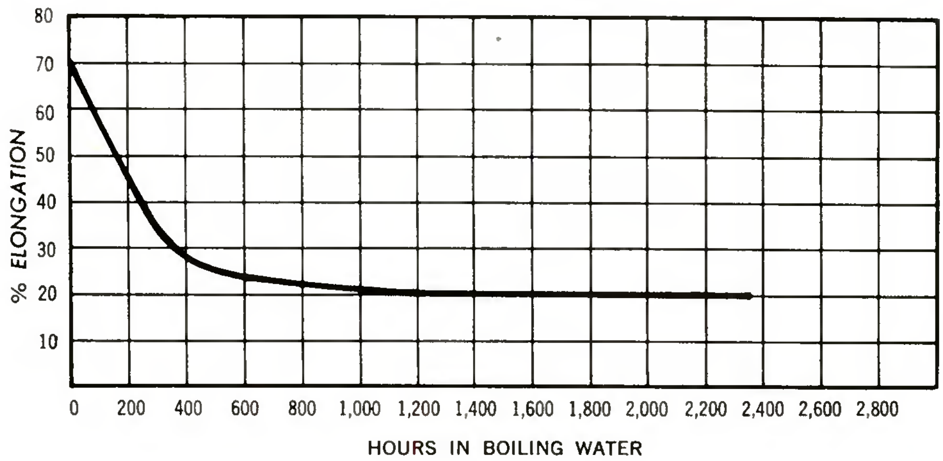
HYDROLYTIC STABILITY

"Kapton" polyimide film is made by a condensation reaction; therefore, its properties are affected by water. Although long-term exposure to boiling water, as shown in the curves below, will reduce the level of film properties, sufficient tensile and elongation remain to insure good mechanical performance. A decrease in the temperature and the water concentration will reduce the rate of "Kapton" property reduction while higher temperatures and pressures will increase it.

TENSILE STRENGTH AFTER EXPOSURE TO 100°C WATER
(Type H Film 1 mil)



ULTIMATE ELONGATION AFTER EXPOSURE IN 100°C WATER
(Type H Film 1 mil)



DIMENSIONAL STABILITY

The dimensional stability of "Kapton" polyimide film depends on two factors—the normal coefficient of thermal expansion and the residual stresses placed in the film during manufacture. The latter causes "Kapton" to shrink on its first exposure to elevated temperatures as indicated in the bar graphs below. Once the film has been exposed, the normal values for thermal expansion listed in Table 2 can be expected.

RESIDUAL SHRINKAGE VS. EXPOSURE TEMPERATURE AND GAUGE
(Type H Film 1 mil)

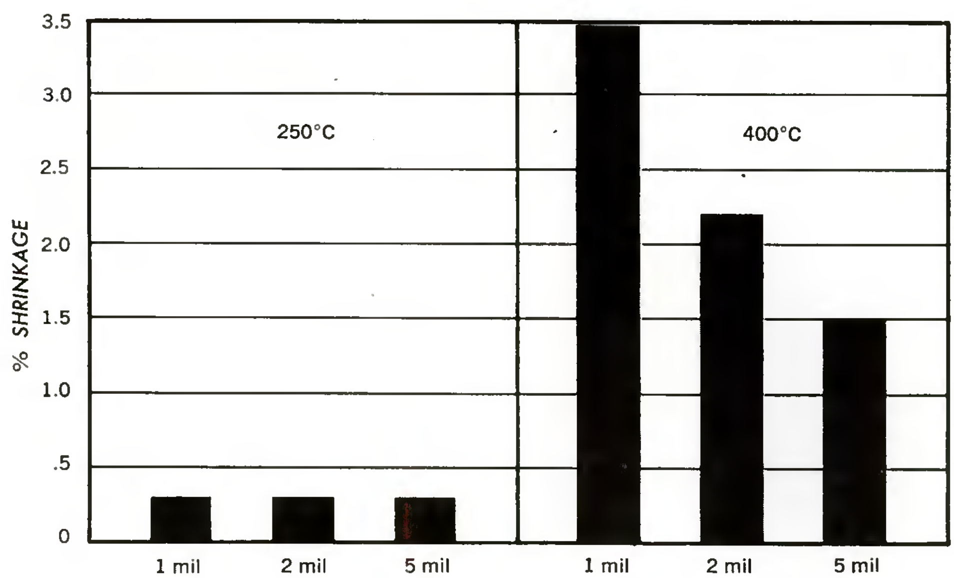


TABLE 2

THERMAL COEFFICIENT OF EXPANSION
(Type H Film 1 mil)
Thermally Exposed

Temperature Range	"K" in/in °C. x 10^5
23-100°C.	1.80
100-200°C.	3.10
200-300°C.	4.85
300-400°C.	7.75
23-400°C.	4.55

CUT-THROUGH AND COLD FLOW

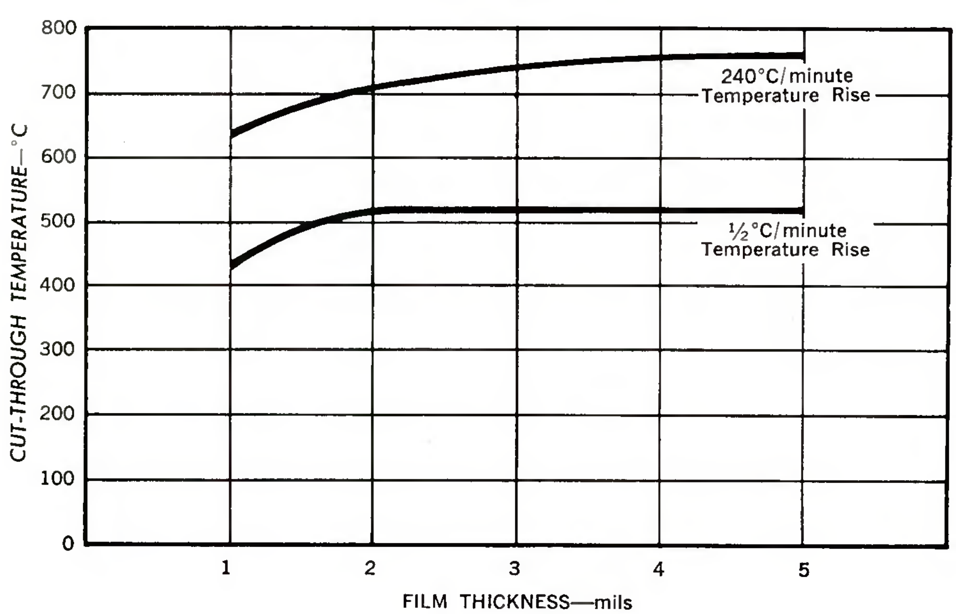
Most organic films exhibit a tendency to flow or thin out under high compressive stresses, especially at elevated temperatures. "Kapton" polyimide film possesses an extremely high resistance to such stresses. Test procedures described in ASTM D-876-61 have been adapted to flat films to provide the data below. Stresses range from an infinitely high point load to 12,000 psi at cut-through for a 1-mil film.

CUT-THROUGH TEMPERATURE

VS.

RATE OF TEMPERATURE RISE AND GAUGE

(Type H Film)

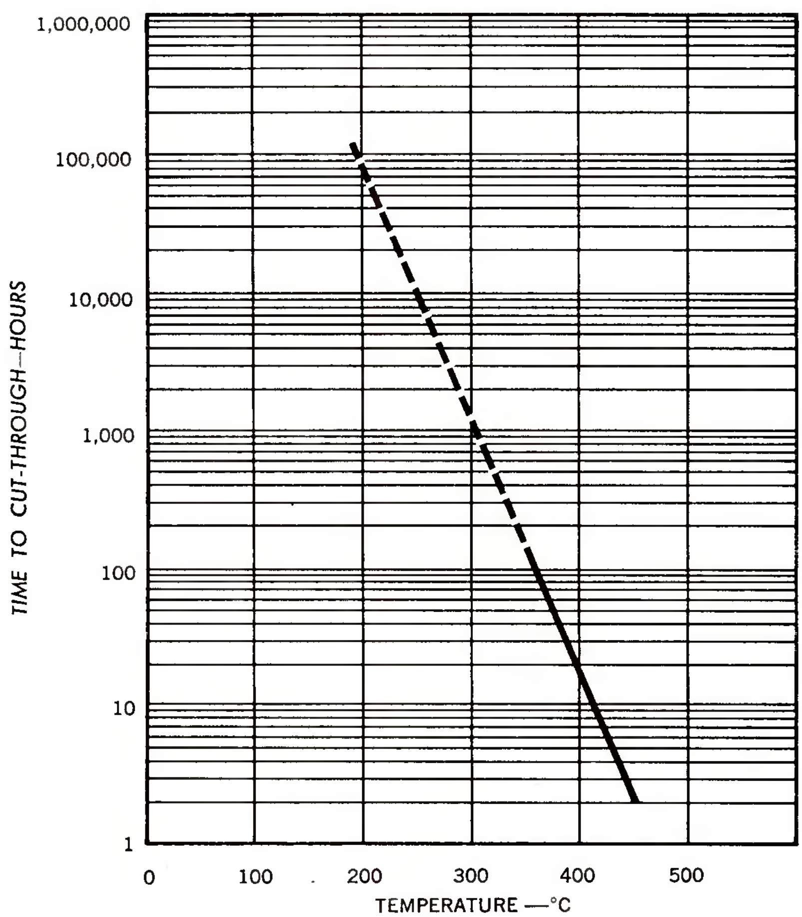


RESISTANCE TO CUT-THROUGH

VS.

TEMPERATURE

(Type H Film—1 mil)



actual

extrapolated

THERMAL AGING

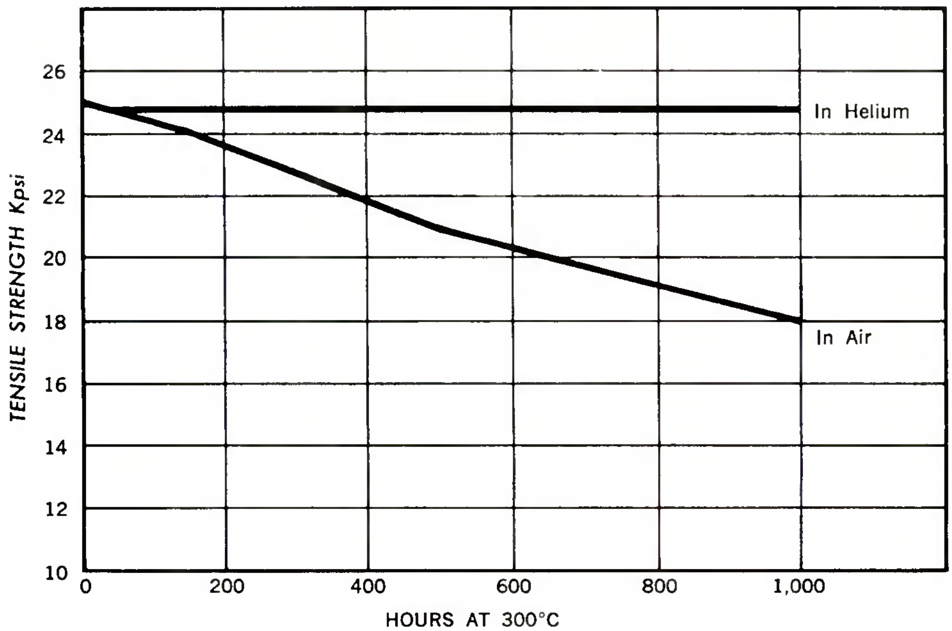
"Kapton" polyimide film is subject to oxidative degradation. Therefore its useful life is a function of both temperature and oxygen concentration in the test environment. The effect of these factors is shown below.

TENSILE STRENGTH

VS.

AGING AT 300°C

TYPE H FILM—1 mil



ULTIMATE ELONGATION

VS.

AGING AT 300°C

TYPE H FILM—1 mil

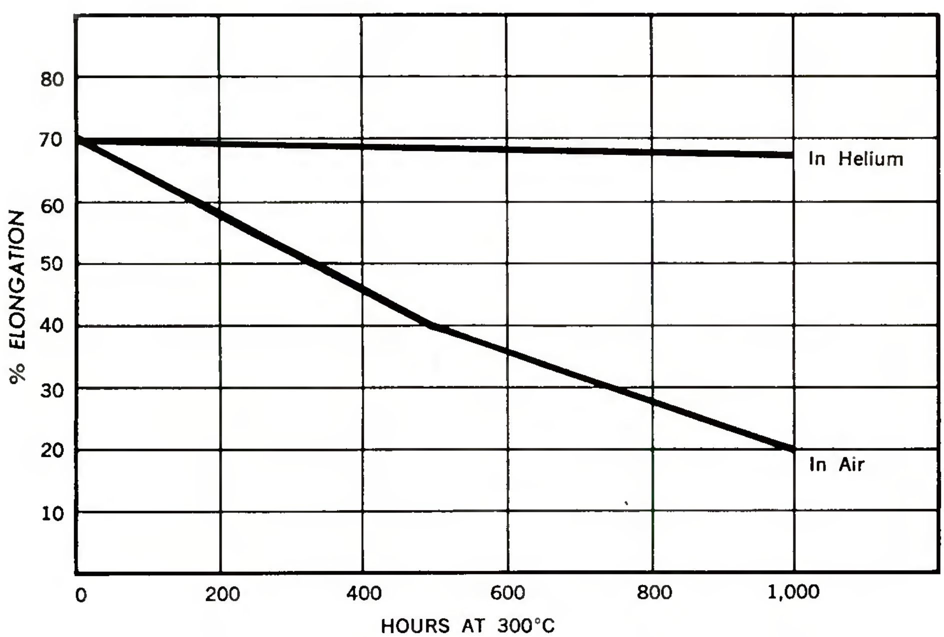


TABLE 3

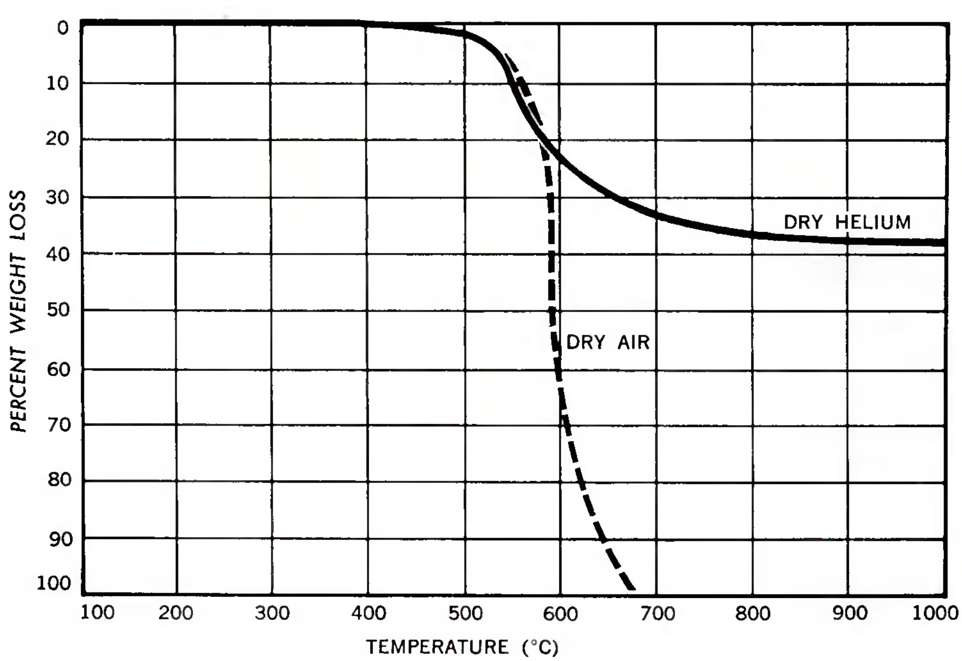
TIME REQUIRED FOR REDUCTION IN ULTIMATE ELONGATION FROM 70% TO 1%

(Type H Film 1 mil)

Temperature	Environment	
	Air	Helium
450°C.	2 hours	22 hours
425°C.	5 hours	3½ days
400°C.	12 hours	2 weeks
375°C.	2 days	2 months
350°C.	6 days	1 year
300°C.	3 months	—
275°C.	1 year	—
250°C.	8 years	—

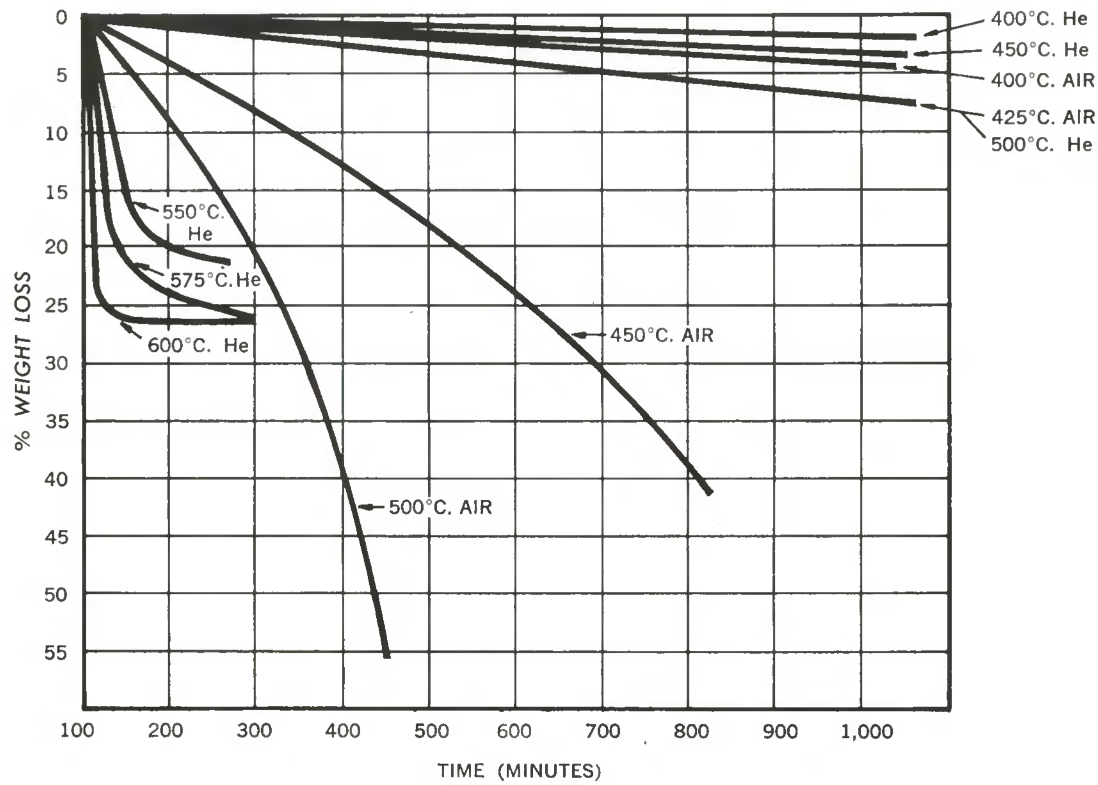
WEIGHT LOSS AT 3°C/MINUTE TEMPERATURE RISE

(Type H Film 1 mil)



ISOTHERMAL WEIGHT LOSS

(Type H Film 1 mil)



NOTE: The values given in this bulletin are typical performance data for "Kapton" Type H film; they are not intended to be used as design data. We believe this information is the best currently available on the subject. It is offered as a possible helpful suggestion in experimentation you may care to undertake along these lines. It is subject to revision as additional knowledge and experience are gained. Du Pont makes no guarantee of results and assumes no obligation or liability whatsoever in connection with this information. This publication is not license to operate under or intended to suggest infringement of, any existing patents.

ELECTRICAL INSULATION PRODUCTS DIVISION
DU PONT FILM DEPARTMENT

ELECTRICAL PROPERTIES

The most common electrical properties of Kapton* polyimide film in various gauges are shown in Table I. These values were measured at 25°C and 50% relative humidity. The effect of such factors as humidity, temperature, and frequency on these basic values are contained in the balance of this bulletin.

TABLE I

TYPICAL ELECTRICAL PROPERTIES OF "KAPTON" POLYIMIDE FILM

PROPERTY	TYPICAL VALUE	TEST CONDITION	TEST METHOD
Dielectric Strength 1 mil 2 mil 3 mil 5 mil	7,000 v/mil 5,400 v/mil 4,600 v/mil 3,600 v/mil	60 cycles ¼" electrodes	ASTM D-149-61
Dielectric Constant 1 mil 2 mil 3 mil 5 mil	3.5 3.6 3.7 3.7	1 kilocycle	ASTM D-150-59T
Dissipation Factor 1 mil 2 mil 3 mil 5 mil	.0025 .0025 .0025 .0027	1 kilocycle	ASTM D-150-59T
Volume Resistivity 1 mil 2 mil 3 mil 5 mil	1×10^{18} ohm-cm 8×10^{17} ohm-cm 5×10^{17} ohm-cm 1×10^{17} ohm-cm	125 volts	ASTM D-257-61
Corona Threshold Voltage 1 mil 2 mil 3 mil 5 mil 5 mil H/2 mil FEP/ 5 mil H/½ mil varnish	465 volts 550 volts 630 volts 800 volts 1,600 volts	60 cycles ¼" electrodes	ASTM 1868-61T

* Reg. U.S. Pat. Off.

EFFECT OF HUMIDITY

Because the water content of "Kapton" polyimide film can affect its electrical properties, electrical measurements were made on 1 mil film after exposure to environments of varying relative humidities at 25°C.

The results of these measurements are given in Table II.

TABLE II

RELATIVE HUMIDITY VS. ELECTRICAL PROPERTIES OF "KAPTON"

% RELATIVE HUMIDITY	AC DIELECTRIC STRENGTH	DIELECTRIC CONSTANT	DISSIPATION FACTOR
0	7,800 v/mil	3.0	.0018
30	7,300 v/mil	3.3	.0021
50	7,000 v/mil	3.5	.0025
80	6,500 v/mil	3.7	.0037
100	6,200 v/mil	3.9	.0047

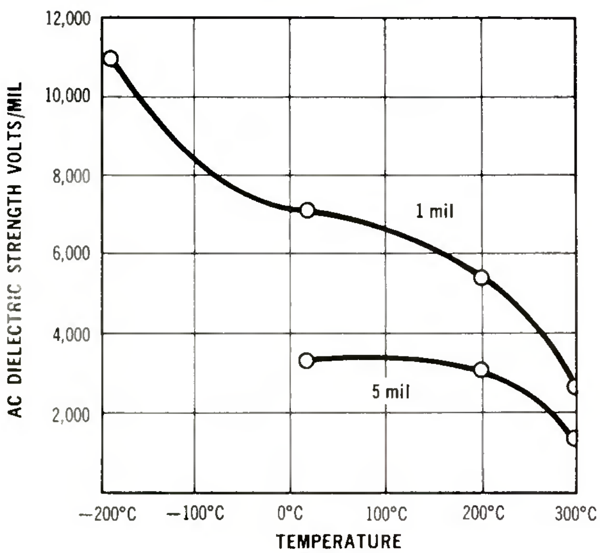
For calculations involving absolute water content, 50% RH in our study is equal to 1.3% water in the film and 100% RH is equal to 2.9% water, the maximum adsorption possible regardless of the driving force.

EFFECT OF TEMPERATURE

As the graphs below indicate, extreme changes in temperature have relatively little affect on the excellent room temperature electrical properties of "Kapton".

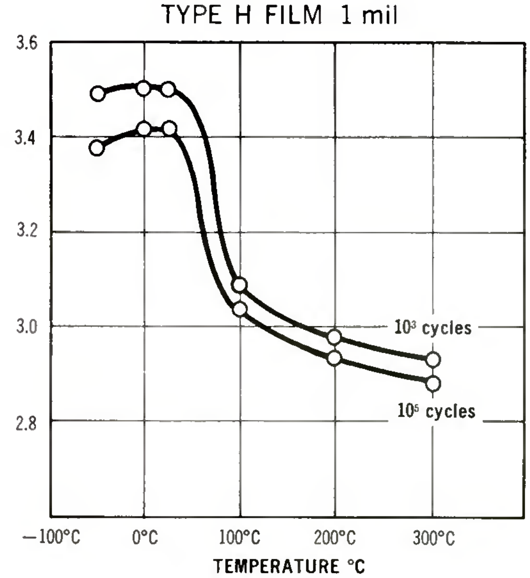
AC DIELECTRIC STRENGTH VS. TEMPERATURE

TYPE H FILM



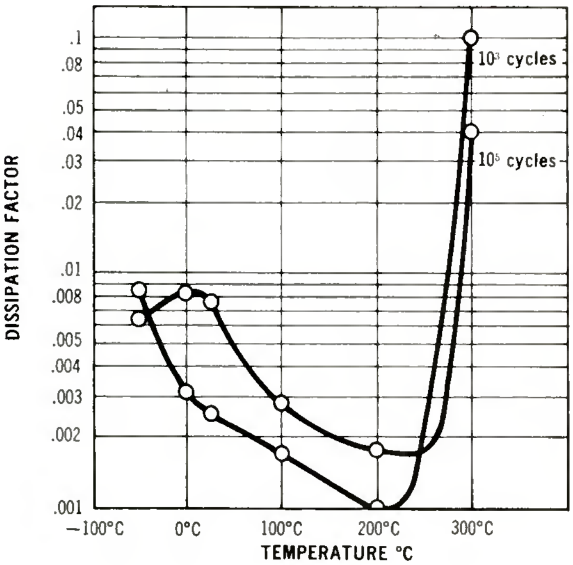
DIELECTRIC CONSTANT VS. TEMPERATURE

TYPE H FILM 1 mil



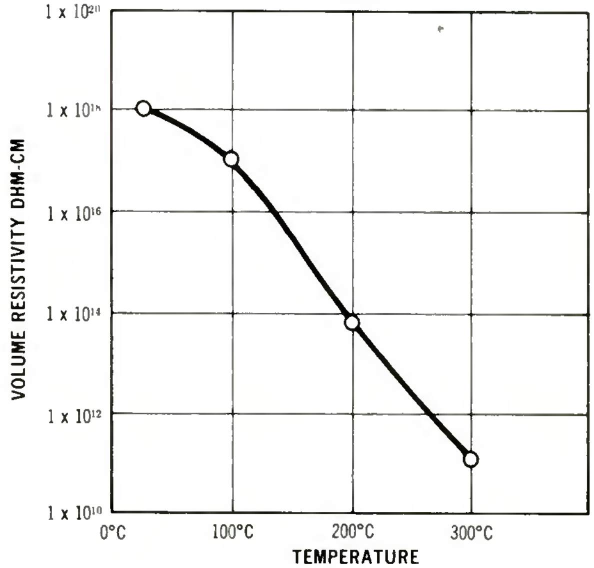
DISSIPATION FACTOR VS. TEMPERATURE

TYPE H FILM 1 mil



VOLUME RESISTIVITY VS. TEMPERATURE

TYPE H FILM 1 mil

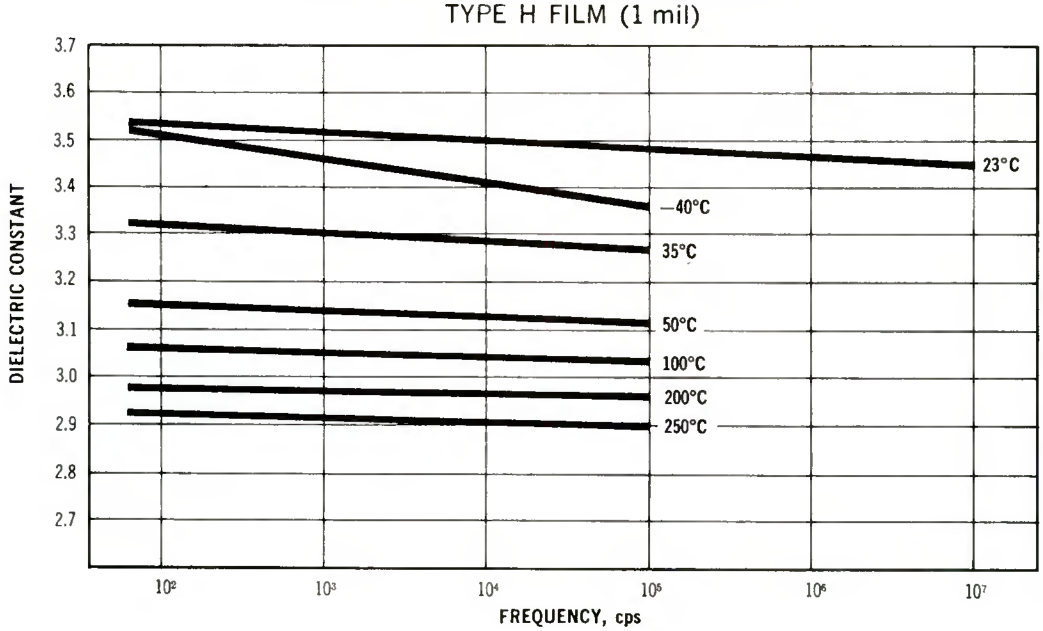


EFFECT OF FREQUENCY

The effects of frequency on the value of the dielectric constant and dissipation factor at various isotherms are shown below.

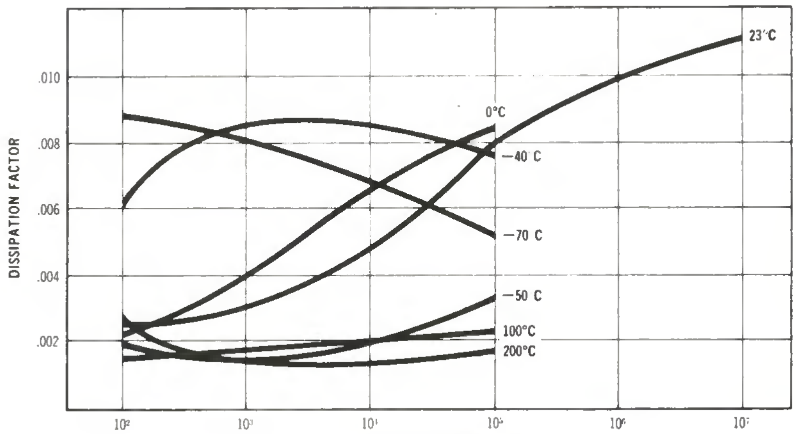
DIELECTRIC CONSTANT VS. FREQUENCY

TYPE H FILM (1 mil)



DISSIPATION FACTOR VS. FREQUENCY

TYPE H FILM (1 mil)



TRACKING RESISTANCE

A 5 mil "Kapton" polyimide film, Type H, has a tracking resistance of 183 seconds as measured by ASTM D-495-61. The failure was due to true tracking rather than erosion, etc.

AC DIELECTRIC LIFE

In many applications the life of "Kapton" at an AC stress which is above the corona threshold level is quite critical. For this reason we made the following measurements. The time figure given represents the failure of the fifth of ten test positions. Electrodes are ¼ inch diameter; temperature is 25°C and AC frequency is 60 cps.

AC DIELECTRIC LIFE

1 mil Type H		5 mil H/2 mil FEP*/5 mil H/ ½ mil varnish	
Corona Threshold Voltage	465 Volts	Corona Threshold Voltage	1600 Volts
VOLTAGE	**LIFE**	**VOLTAGE**	**LIFE**
1,000 volts	30,000 seconds		
2,500	2,990	6,000 volts	525 hours
3,000	1,260	9,000	25
4,000	265		
4,500	144		
5,000	72		
5,500	33		
6,000	18		
6,500	9		

*Du Pont "Teflon" FEP-fluorocarbon resin

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Application Note

MOUNTING TECHNIQUES FOR POWER SEMICONDUCTORS

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For reliable operation, semiconductors must be properly mounted. Discussed are aspects of preparing the mounting surface, using thermal compounds, insulation techniques, fastening techniques, handling of leads and pins, and evaluation methods for the thermal system.

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MOUNTING TECHNIQUES FOR POWER SEMICONDUCTORS

INTRODUCTION

Current and power ratings of semiconductors are inseparably linked to their thermal environment. Except for lead-mounted parts used at low currents, a heat exchanger is required to prevent the junction temperature from exceeding its rated limit, thereby running the risk of a high failure rate. Furthermore, semiconductor-industry field history indicates that the failure rate of most silicon semiconductors decreases approximately by one half for a decrease in junction temperature from 160°C to 135°C.*

Many failures of power semiconductors can be traced to faulty mounting procedures. With metal packaged devices, faulty mounting generally causes unnecessarily high junction temperature, resulting in reduced component lifetime, although mechanical damage has occurred on occasion from mounting securely to a warped surface. With the widespread use of various plastic-packaged semiconductors, the dimension of mechanical damage becomes very significant.

Figure 1 shows an example of doing nearly everything wrong. In this instance, the device to be victimized is in the TO-220 package. The leads are bent to fit into a socket—an operation which, if not properly done, can crack the package, break the bonding wires, or crack the die. The package is fastened with a sheet-metal screw through a 1/4"-hole containing a fiber-insulating sleeve. The force used to tighten the screw pulls the package into the hole, causing enough distortion to crack the die. Even if the die were not cracked, the contact area is small because of the area consumed by the large hole and the bowing of the package; the result is a much higher junction temperature than expected. If a rough heat sink surface and some burrs around the hole are present, many—but unfortunately not all—poor mounting practices are covered.

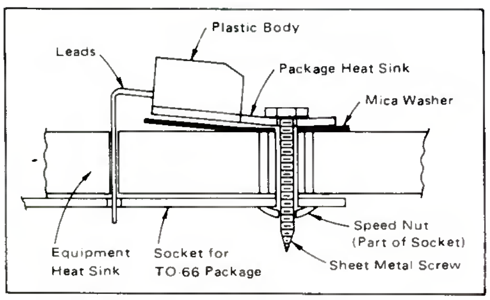


FIGURE 1 — Extreme Case of Improperly Mounting A Semiconductor (Distortion Exaggerated)

*See MIL-Handbook—217B, Section 2.2

In many situations the case of the semiconductor must be isolated electrically from its mounting surface. The isolation material is, to some extent, a thermal isolator as well, which raises junction operating temperatures. In addition, the possibility of arc-over problems is introduced if high voltages are being handled. Electrical isolation thus places additional demands upon the mounting procedure.

Proper mounting procedures necessitate attention to the following areas:

1. Mounting surface preparation,
2. Application of thermal compounds,
3. Installation of the insulator,
4. Fastening of the assembly, and
5. Lead bending and soldering.

In this note, the procedures are discussed in general terms. Specific details for each class of packages are given in the figures and in Table 1. Appendix A contains a brief review of thermal resistance concepts, and Appendix B lists sources of supply for accessories. Motorola supplies hardware for all power packages. It is detailed on separate data sheets for each package type.

MOUNTING SURFACE PREPARATION

In general, the heat-sink mounting surface should have a flatness and finish comparable to that of the semiconductor package. In lower power applications, the heat-sink surface is satisfactory if it appears flat against a straight edge and is free from deep scratches. In high-power applications, a more detailed examination of the surface is required.

Surface Flatness

Surface flatness is determined by comparing the variance in height (Δh) of the test specimen to that of a reference standard as indicated in Figure 2. Flatness is normally specified as a fraction of the Total Indicator Reading (TIR). The mounting surface flatness, i.e., $\Delta h/TIR$, is satisfactory in most cases if less than 4 mils per inch, which is normal for extruded aluminum—although disc type devices usually require 1 mil per inch.

Surface Finish

Surface finish is the average of the deviations both above and below the mean value of surface height. For minimum interface resistance, a finish in the range of 50 to 60 microinches is satisfactory;* a finer finish is costly to achieve and does not significantly lower contact resistance. Most commercially available cast or extruded

*Tests run by Thermalloy (Catalog #74-INS-3, page 14) using a copper TO-3 package with a typical 32-microinch finish, showed that finishes between 16 and 64 μ-in caused less than ±2.5% difference in interface thermal resistance.

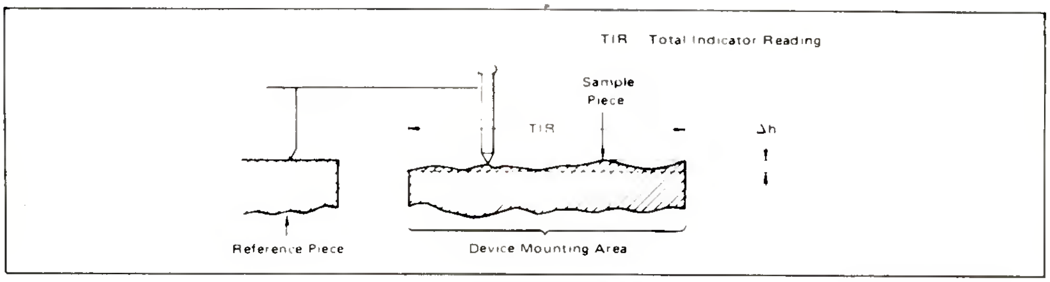


FIGURE 2 — Surface Flatness

heat sinks will require spotfacing when used in high-power applications. In general, milled or machined surfaces are satisfactory if prepared with tools in good working condition.

Mounting holes generally should only be large enough to allow clearance of the fastener. The larger packages having mounting holes removed from the semiconductor die location, such as a TO-3, may successfully be used with larger holes to accommodate an insulating bushing, but Thermopad plastic packages are intolerant of this condition. For these packages, a smaller screw size must be used such that the hole for the bushing does not exceed the hole in the package.

Punched mounting holes have been a source of trouble because if not properly done, the area around a punched hole is depressed in the process. This "crater" in the heat sink around the mounting hole can cause two problems. The device can be damaged by distortion of the package as the mounting pressure attempts to conform it to the shape of the heat-sink indentation, or the device may only bridge the crater and leave a significant percentage of its heat-dissipating surface out of contact with the heat sink. The first effect may often be detected immediately by visual cracks in the package (if plastic), but usually an unnatural stress is imposed, which results in an early-life failure. The second effect results in hotter operation and is not manifested until much later.

Although punched holes are seldom acceptable in the relatively thick material used for extruded aluminum heat sinks, several manufacturers are capable of properly utilizing the capabilities inherent in both fine-edge blanking or sheared-through holes when applied to sheet metal as commonly used for stamped heat sinks. The holes are pierced using Class A progressive dies mounted on four-post die sets equipped with proper pressure pads and holding fixtures.

When mounting holes are drilled, a general practice with extruded aluminum, surface cleanup is important. Chamfers must be avoided because they reduce heat transfer surface and increase mounting stress. The edges should be broken to remove burrs which cause poor contact between device and heat sink and may puncture isolation material.

Many aluminum heat sinks are black-anodized to improve radiation ability and prevent corrosion. Anodizing results in significant electrical but negligible thermal insulation. It need only be removed from the mounting area when electrical contact is required. Another treated aluminum finish is iridite, or chromate-acid dip, which offers low resistance because of its thin surface, yet has good electrical properties because it resists oxidation. It need only be cleaned of the oils and films that collect in the manufacture and storage of the sinks, a practice which should be applied to all heat sinks. For economy, paint is sometimes used for sinks; removal of the paint where the semiconductor is attached is usually required because of paint's high thermal resistance. However, when it is necessary to insulate the semiconductor package from the heat sink, anodized or painted surfaces may be more effective than other insulating materials which tend to creep (i.e., they flow), thereby reducing contact pressure.

It is also necessary that the surface be free from all foreign material, film, and oxide (freshly bared aluminum forms an oxide layer in a few seconds). Unless used immediately after machining, it is a good practice to polish the mounting area with No. 000 steel wool, followed by an acetone or alcohol rinse. Thermal grease should be immediately applied thereafter and the semiconductor attached as the grease readily collects dust and metal particles.

THERMAL COMPOUNDS

To improve contacts, thermal joint compounds or greases are used to fill air voids between all mating surfaces. Values of thermal resistivity vary from 0.10 degrees Celsius-inches per watt for copper film to 1200°C-in/W for air, whereas satisfactory joint compounds will have a resistivity of approximately 60°C-in/W. Therefore, the voids, scratches, and imperfections which are filled with a joint compound, will have a thermal resistance of about 1/20th of the original value which makes a significant reduction in the overall interface thermal resistance.

Joint compounds are a formulation of fine zinc particles in a silicon oil which maintains a grease-like consistency with time and temperature. Since some of these compounds do not spread well, they should be evenly applied in a very thin layer using a spatula or lintless brush, and wiped lightly to remove excess material. Some cyclic rotation of the package will help the compound spread evenly over the entire contact area. Experience will indicate whether the quantity is sufficient, as excess will appear around the edges of the contact area. To prevent accumulation of airborne particulate matter, excess compound should be wiped away using a cloth moistened with acetone or alcohol. These solvents should not contact plastic-encapsulated devices, as they may enter the package and cause a leakage path or carry in substances which might attack the assembly.

Data showing the effect of compounds on several package types under different mounting conditions is shown in Table I. The rougher the surface, the more valuable the grease becomes in lowering contact resistance; therefore, when mica insulating washers are used, use of grease is generally mandatory. The joint compound also improves the breakdown rating of the insulator and is therefore highly desirable despite the handling problems created by its affinity for foreign matter. Some sources of supply for joint compounds are shown in Appendix B.

Some users and heat-sink manufacturers prefer not to use compounds. This necessitates use of a heat sink with lower thermal resistance which imposes additional cost, but which may be inconsequential when low power is being handled. Others design on the basis of not using grease, but apply it as an added safety factor, so that if improperly applied, operating temperatures will not exceed the design values.

TABLE 1

Approximate Values for Interface Thermal Resistance and Other Package Data

(See Table II for Case Number to JEDEC Outline Cross-Reference)

Dry interface values are subject to wide variation because of extreme dependence upon surface conditions. Unless otherwise noted the case temperature is monitored by a thermocouple located directly under the die reached through a hole in the heat sink. (See Note 4.)

Package Type and Data					Interface Thermal Resistance (°C/W)					
JEDEC Outline	Description	Recommended Mounting Hole and Drill Size	Machine Screw Size[2]	Torque In-Lb	Metal-to-Metal Dry	Metal-to-Metal Lubed	With Insulator Dry	With Insulator Lubed	With Insulator Type	See Note
Case 152*	Uniwatt	0.113, #33	4-40	6	5.0	3.8	7.4	5.4	2 mil Mica	3
DO-4	10-32 Stud 7/16" Hex	0.188, #12	10-32	20	0.3	0.2	1.6	0.8	3 mil Mica	
DO-5	1/4-28 Stud 11/16" Hex	0.250, #1	1/4-28	25	0.2	0.1	0.8	0.6	5 mil Mica	
DO-21	Pressfit, 1/2"	See Figure 8	—	—	0.15	0.10	—	—	—	
TO-3	Diamond Flange	0.140, #28	6-32	6	0.5	0.1	1.3	0.36	3 mil Mica	1
TO-66	Diamond Flange	0.140, #28	6-32	6	1.5	0.5	2.3	0.9	2 mil Mica	
TO-83 TO-94	1/2" 20 Stud 1-1/16" Hex	0.5, 0.5 —	1/2-20	130	—	0.1	—	—	—	
TO-126	Thermopad 1/4" x 3/8"	0.113, #33	4-40	6	2.0	1.3	4.3	3.3	2 mil Mica	
TO-127	Thermopad 1/2" x 5/8"	0.140, #28	6-32	8	1.6	0.8	2.6	1.8	2 mil Mica	
TO-202AC	Duowatt	0.140, #28	6-32	8	1.3	0.9	4.8	2.0	2 mil Mica	3
TO-220AB	Thermowatt	0.140, #28	6-32	8	1.2	1.0	3.4	1.6	2 mil Mica	1, 2

*Motorola Case Number

NOTE 1. See Figures 3 and 4 for additional data on TO-3 and TO-220 packages.

NOTE 2. Screw not insulated.

NOTE 3. Case thermocouple soldered to top of tab.

NOTE 4. **Measurement of Interface Thermal Resistance.** Measuring the interface thermal resistance $R_{\theta CS}$ appears deceptively simple. All that's apparently needed is a thermocouple on the semi, a thermocouple on the heat sink, and a means of applying and measuring DC power. However, $R_{\theta CS}$ is proportional to the amount of contact area between the surfaces and consequently is affected by surface flatness and finish and the amount of pressure on the surfaces. In addition, placement of the thermocouples can have a significant influence upon the results. Consequently, values for interface thermal resistance presented by different manufacturers are in poor agreement.

Consider the TO-220 package shown in the accompanying figure. The mounting pressure at one end causes the other end—where the die is located— to lift off the mounting surface slightly. To improve contact, Motorola TO-220 packages are slightly concave and use of a spreader bar under the screw lessens the lifting, but some is inevitable with a single-ended package.

The thermocouple locations are shown:

a. The Motorola location is directly under the die reached through a hole in the heat sink. The thermocouple is held in place by a spring which forces the thermocouple into intimate contact with the bottom of the semi's case.

b. The EIA location is close to the die on the top surface of the package base reached through a blind hole drilled through the molded body. The thermocouple is swaged in place.

c. The Thermalloy location is on the top portion of the tab between the molded body and the mounting screw. The thermocouple is soldered into position.

Temperatures at the three locations are generally not the same. Consider the situation depicted in the figure. Because the only area of direct contact is around the mounting screw, nearly all the heat travels horizontally along the tab from the die to the contact area. Consequently, the temperature at the EIA location is hotter than at the Thermalloy location and the Motorola location is even hotter. Since junction-to-sink thermal resistance is constant for a given setup, junction-to-case values decrease and case-to-sink values increase as the case thermocouple readings become warmer.

There are examples where the relationship between the thermocouple temperatures are different from the previous situation. If a mica washer with grease is installed between the semi package and the heat sink, tightening the screw will not bow the package;

Table 1, Note 5 (continued)

instead, the mica will be deformed. The primary heat conduction path is from the die through the mica to the heat sink. In this case, a small temperature drop will exist across the vertical dimension of the package mounting base so that the thermocouple at the EIA location will be the hottest. The thermocouple temperature at the Thermalloy location could be close to the temperature at the EIA location as the lateral heat flow is generally small.

The EIA location is chosen to obtain the highest temperature on the case. It is of significance because power ratings are supposed to be based on this reference point. Unfortunately, the placement of the thermocouple is tedious and leaves the semiconductor in a condition unfit for sale.

The Motorola location is chosen to obtain the highest temperature of the case at a point where, hopefully, the semi is making contact to the heat sink, since heat sinks are measured from the point of semi contact to the ambient. Once the special heat sink to accommodate the thermocouple has been fabricated, this method lends itself to production testing and does not mark the device. However, this location is not easily accessible to the user.

The Thermalloy location is convenient and is often chosen by equipment manufacturers. However, it also blemishes the case and may yield results differing up to 1°C/W for a TO-220 package mounted to a heat sink without thermal grease and no insulator. This error is small when compared to the heat dissipators often used with this package, since power dissipation is usually a few watts. When compared to the specified junction-to-case values of some of the higher power semiconductors becoming available, however, the difference becomes significant, and it is important that the semiconductor manufacturer and equipment manufacturer use the same reference point.

Another method of establishing reference temperatures utilizes a soft copper washer (thermal grease is used) between the semiconductor package and the heat sink. The washer is flat to within 1 mil/inch, has a finish better than 63 μ-inch, and has an imbedded thermocouple near its center. This reference includes the interface resistance under nearly ideal conditions and is therefore application-oriented. It is also easy to use and yields reproducible results. At this printing, however, sufficient data to compare results to other methods is not available.

The only way to get accurate measurements of the interface resistance is to also test for junction-to-case thermal resistance at the same time. If the junction-to-case values remain relatively constant as insulators are changed, torque varied, etc., then the case reference point is satisfactory.

JEDEC TO-220 Package mounted to heat sink showing various thermocouple locations and lifting caused by pressure at one end.

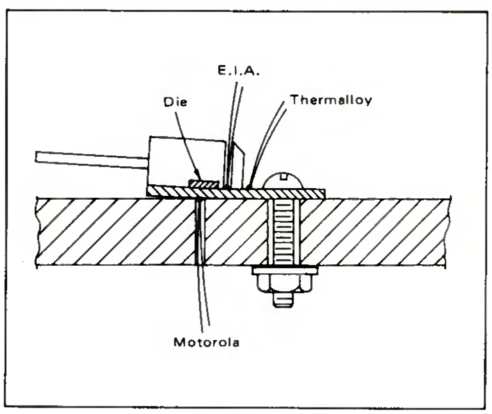


TABLE 2

Cross Reference Chart

Motorola Case Number to JEDEC Outline Number and Table 1 Reference

Motorola Number	JEDEC Number	Reference in Table 1
1	TO-3	TO-3
3	TO-3[2]	TO-3
9	TO-61	DO-5
11	TO-3	TO-3
11A	TO-3[2]	TO-3
12	TO-3[2]	TO-3
36	TO-60	DO-4
42A	DO-5	DO-5
44	DO-4	DO-4
54	TO-3[2]	TO-3
56	DO-4	DO-4
58	DO-5[2]	DO-5
77	TO-126	TO-126
80	TO-66	TO-66
86	TO-208[1]	DO-4
86L	TO-298[1]	DO-4
90	TO-127	TO-127
145C	TO-232[1]	DO-4
152	TO-202[1]	Case 152
160-03	TO-59	DO-4
167	DO-203[1] – 1.25" hex	DO-4
157	DO-203[1]	DO-5
197	TO-3[2]	TO-3
199	TO-225[1]	TO-127
219	TO-94	TO-83
221	TO-220AB	TO-220AB
221A	TO-220AB	TO-220AB
235	TO-208[1]	DO-5
238	TO-208[1]	DO-5
239	TO-208	—
245	DO-4	DO-4
246	TO-83	TO-83
257-01	DO-5	DO-5
263	TO-208[1]	DO-5
283	DO-4	DO-4
285	TO-209[1]	TO-83
288	TO-208[1]	TO-83
289	TO-209[1]	DO-5
291	TO-94	TO-83
306	TO-202AC	TO-202AC

NOTE 1. Would fit within this family outline if registered with JEDEC.

NOTE 2. Not within all JEDEC outline dimensions. The data in Table 1 and suggested mounting hardware and procedures generally apply.

INSULATION CONSIDERATIONS

Since it is most expedient to manufacture power semiconductors with collectors or anodes electrically common to the case, the problem of isolating this terminal from ground is a common one. For lowest overall thermal resistance, it is best to isolate the entire heat sink/semiconductor structure from ground, rather than to use an insulator between the semiconductor and the heat sink. Where heat sink isolation is not possible, because of safety reasons or in instances where a chassis serves as a heat sink or where a heat sink is common to several devices, insulators are used to isolate the individual components from the heat sink.

When an insulator is used, thermal grease assumes greater importance than with a metal-to-metal contact, because two interfaces exist instead of one and some materials, such as mica, have a markedly uneven surface. Reduction of interface thermal resistance of between 2 to 1 and 3 to 1 are typical when grease is used.

Data obtained by Thermalloy, showing interface resistance for different insulators and torque applied to TO-3 and TO-220 packages, are shown in Figure 3 for bare surfaces and Figure 4 for greased surfaces. It is obvious that with some arrangements, the interface thermal resistance exceeds that of the semiconductor (junction to case). When high power is handled, beryllium oxide is unquestionably the best choice. Thermafilm is Thermalloy's tradename for a polyimide material which is also commonly known as Kapton*; this material is fairly popular for low power applications because it is low cost, withstands high temperatures and is easily handled, in contrast to mica which chips and flakes easily.

When using insulators, care must be taken to keep the mating surfaces clean. Small particles of foreign matter can puncture the insulation, rendering it useless or seriously lowering its dielectric strength. In addition, particularly when voltages higher than 300 V are encountered, problems with creepage may occur. Dust and other foreign material can shorten creepage distances significantly so that having a clean assembly area is important. Surface roughness and humidity also lower insulation resistance. Use of thermal grease usually raises the breakdown voltage of the insulation system. Because of these factors, which are not amenable to analysis, hi-pot testing should be done on prototypes and a large margin of safety employed. In some situations, it may be necessary to substitute "empty" packages for the semiconductors to avoid shorting them or to prevent the semiconductors from limiting the voltage applied during the hi-pot test.

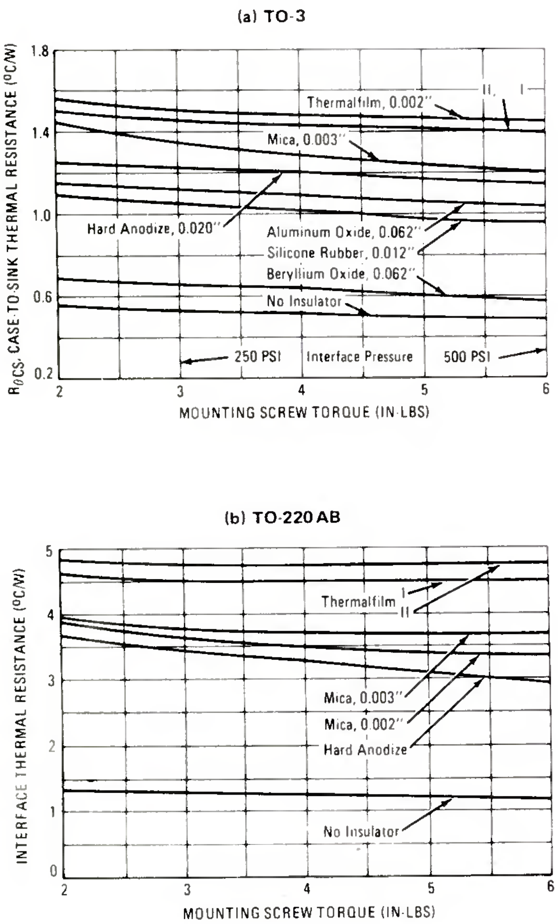


FIGURE 3 – Interface Thermal Resistance Without Thermal Grease as a Function of Mounting Screw Torque Using Various Insulating Materials

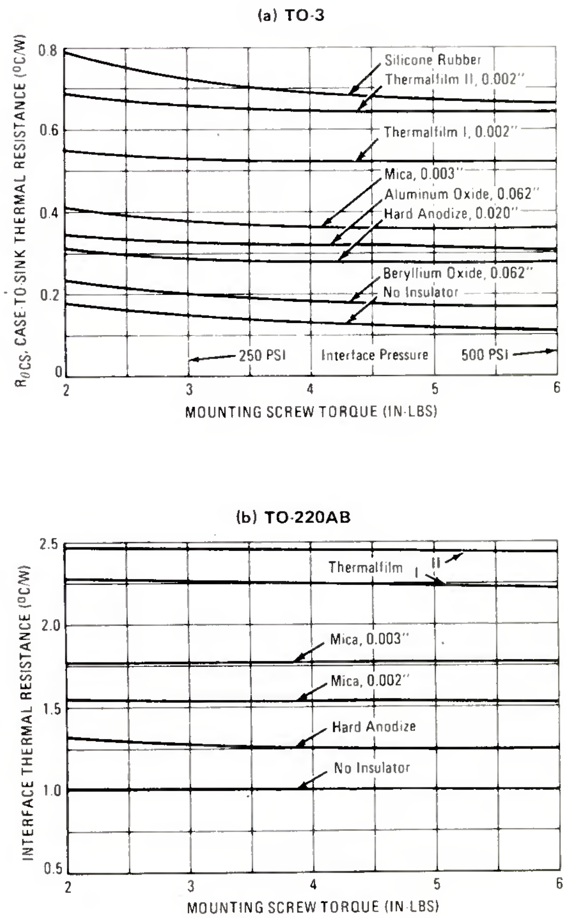


FIGURE 4 – Interface Thermal Resistance Using Thermal Grease as a Function of Mounting Screw Torque Using Various Insulating Materials

*® DuPont

FASTENER AND HARDWARE CHARACTERISTICS

Characteristics of fasteners, associated hardware, and the tools to secure them determine their suitability for use in mounting the various packages. Since many problems have arisen because of improper choices, the basic characteristics of several types of hardware are discussed next.

Compression Washers

A very useful piece of hardware is the bell-type compression washer. As shown in Figure 5, it has the ability to maintain a fairly constant pressure over a wide range of physical deflection–generally 20% to 80%–thereby maintaining an optimum force on the package. When installing, the assembler applies torque until the washer depresses to half its original height. (Tests should be run prior to setting up the assembly line to determine the proper torque for the fastener used to achieve 50% deflection.) The washer will absorb any cyclic expansion of the package or insulating washer caused by temperature changes. Bell type washers are the key to successful mounting of devices requiring strict control of the mounting force or when plastic hardware is used in the mounting scheme.

Motorola washers designed for use with the Thermopad package maintain the proper force when properly secured. They are used with the large face contacting the packages.

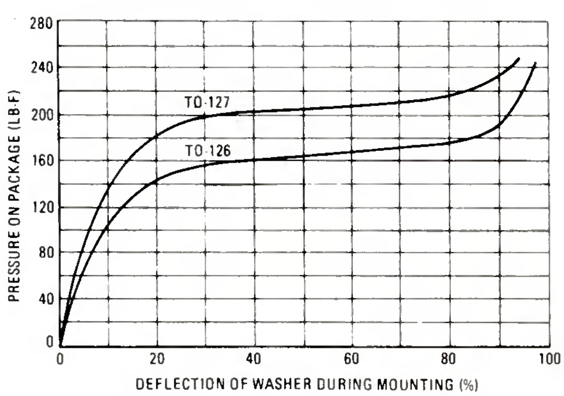


FIGURE 5 – Characteristics of the Bell Compression Washers Designed for Use with Thermopad Semiconductors

Machine Screws

Machine screws and nuts form a trouble-free fastener system for all types of packages which have mounting holes. Torque ratings apply when dry; therefore, care must be exercised when using thermal grease to prevent it from getting on the threads as inconsistent torque readings result. Machine screw heads should not directly contact the surface of any of the Thermopad plastic package types as the screw heads are not sufficiently flat to provide properly distributed force.

Self-Tapping Screws

Under some conditions, sheet-metal screws are acceptable. However, during the tapping process with a standard screw, a volcano-like protrusion will develop in the metal being threaded; a very unsatisfactory surface results. When used, a speed-nut must be used to secure a standard screw, or the type of screw must be used which roll-forms machine screw threads.

Eyelets

Successful mounting can also be accomplished with hollow eyelets provided an adjustable, regulated pressure press is used such that a gradually increasing pressure is used to pan the eyelet. Use of sharp blows could damage the semiconductor die.

Rivets

When a metal flange-mount package is being mounted directly to a heat sink, rivets can be used. Rivets are not a recommended fastener for any of the plastic packages except for the tab-mount type. Aluminum rivets are preferred over steel because less pressure is required to set the rivet and thermal conductivity is improved.

Insulators and Plastic Hardware

Because of its relatively low cost and low thermal resistance, mica is still widely used to insulate semiconductor packages from heat sinks despite its tendency to chip and flake. It has a further advantage in that it does not creep or flow so that the mounting pressure will not reduce with time in use. Plastic materials, particularly Teflon*, will flow. When plastic materials form parts of the fastening system, a compression washer is a valuable addition which assures that the assembly will not loosen with time.

FASTENING TECHNIQUES

Each of the various types of packages in use requires different fastening techniques. Details pertaining to each type are discussed in following sections. Some general considerations follow.

To prevent galvanic action from occurring when devices are used on aluminum heat sinks in a corrosive atmosphere, many devices are nickel- or gold-plated. Consequently, precautions must be taken not to mar the finish.

Manufacturers which provide heat sinks for general use and other associated hardware are listed in Appendix B. Manufacturer's catalogs should be consulted to obtain more detailed information. Motorola also has mounting hardware available for a number of different packages. Consult the Hardware Data Sheet for dimensions of the components and part numbers.

Specific fastening techniques are discussed in the remainder of this note for the following categories of semiconductor package.

1. Stud mount: DO-4, DO-5, DO-9, DO-30, TO-59, TO-60/63, TO-83, TO-93/94, etc.
2. Flange mount: DO-43, DO-44, TO-3, TO-37, TO-41, TO-53, TO-66, etc.
3. Pressfit: DO-21, DO-24, TO-203
4. Disc: DO-200 and TO-200 Families
5. Thermopad®: TO-126/7
6. Thermowatt®: TO-220 Family
7. Tab Mount (Duowatt® and Uniwatt®): TO-202 Family
8. RF Stripline: TO-119/121, TO-128/9, TO-216

*Trademark E. I. DuPont

Stud Mount

Mounting errors with stud-mounted parts are generally confined to application of excessive torque or tapping the stud into a threaded heat-sink hole. Both these practices may cause a warpage of the hex base which may crack the semiconductor die. The best fastening method is to use a nut and washer; the details are shown in Figure 6.

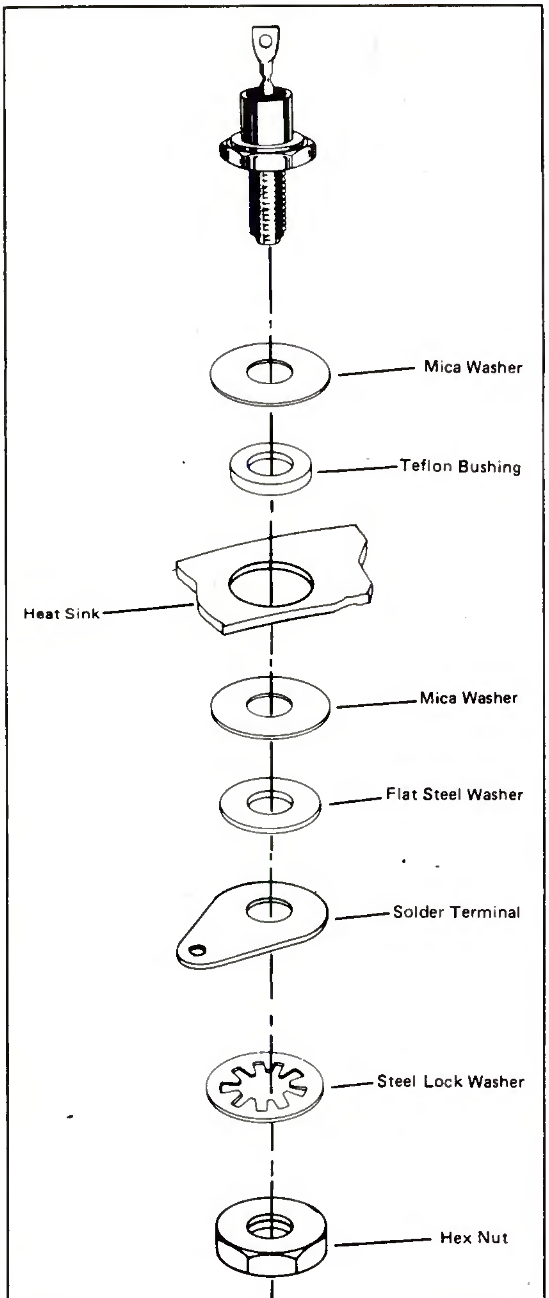


FIGURE 6 – Mounting Details For Stud-Mounted Semiconductors

Flange Mount

Few known mounting difficulties exist with this type of package. The rugged base and distance between die and mounting holes combine to make it extremely difficult to cause any warpage unless mounted on a surface which is badly bowed or unless one side is tightened excessively before the other screw is started. A typical mounting installation is shown in Figure 7. Machine screws, self-tapping screws, eyelets, or rivets may be used to secure the package.

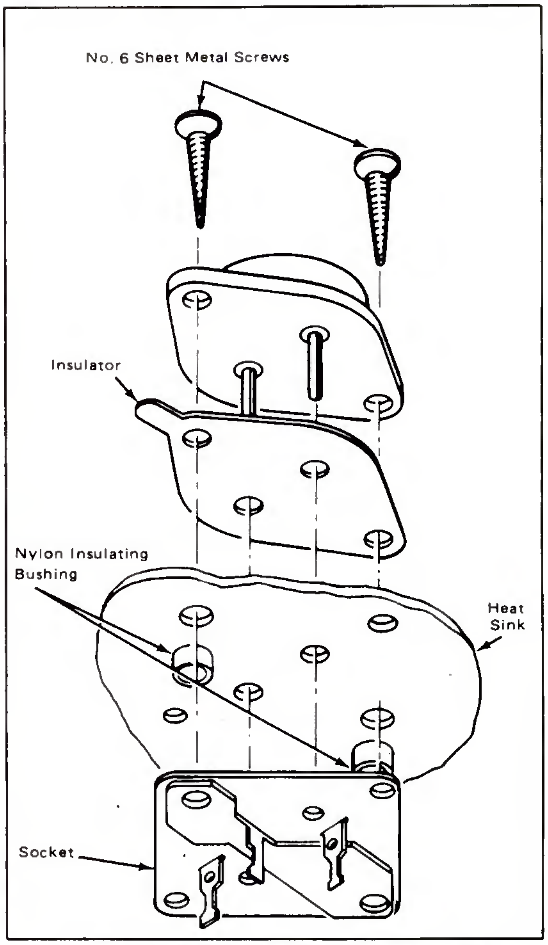


FIGURE 7 – Mounting Details for Flat-Base Mounted Semiconductors (TO-3 Shown).

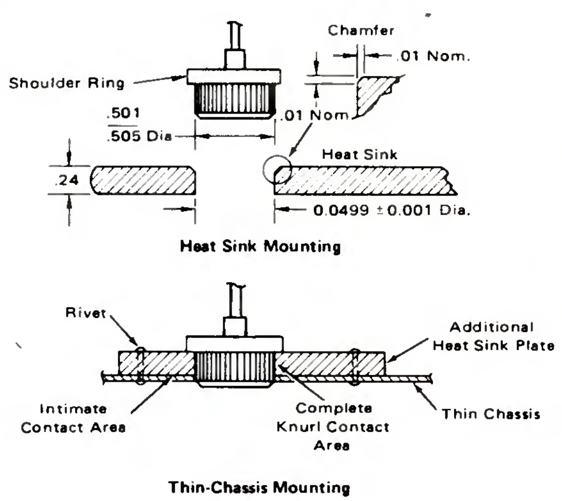
When not using a socket, machine screws tightened to their torque limits will produce lowest thermal resistance.

Press Fit

For most applications, the press-fit case should be mounted according to the instructions shown in Figure 8. A special fixture meeting the necessary requirements is a must.

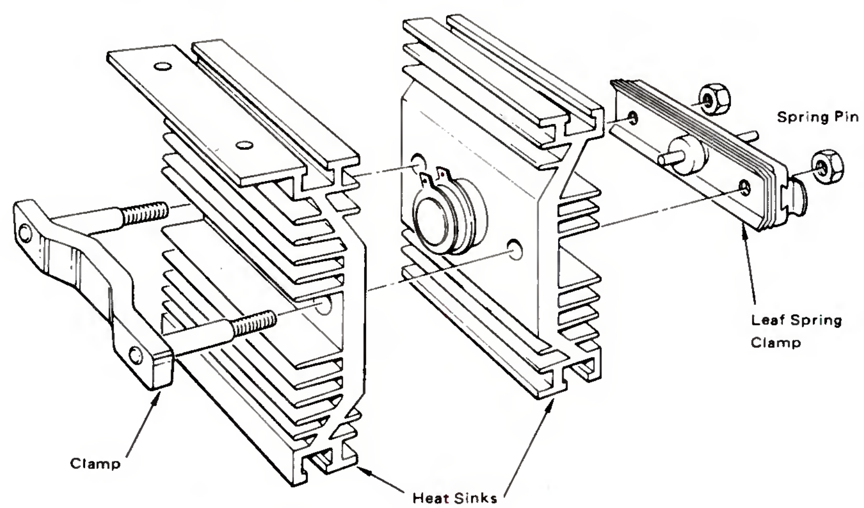
Disc

Disc type devices also require special handling. The details are shown in Figure 9.



The hole edge must be chamfered as shown to prevent shearing off the knurled edge of the case during press-in. The pressing force should be applied evenly on the shoulder ring to avoid tilting or canting of the case in the hole during the pressing operation. Also, the use of a thermal joint compound will be of considerable aid. The pressing force will vary from 250 to 1000 pounds, depending upon the heat-sink material. Recommended hardnesses are: copper—less than 50 on the Rockwell F scale; aluminum—less than 65 on the Brinell scale. A heat sink as thin as 1/8" may be used, but the interface thermal resistance will increase in direct proportion to the contact area. A thin chassis requires the addition of a backup plate.

FIGURE 8 — Mounting Details for Press-Fit Semiconductors



A self-leveling type mounting clamp is recommended to assure parallelism and even distribution of pressure on each contact area. A swivel type clamp or a narrow leaf spring in contact with the heat dissipator provides acceptable performance.

The clamping force should be applied smoothly, evenly, and perpendicularly to the semiconductor package to prevent deformation of the device or the heat-dissipator mounting surfaces during installation. The spring used should provide a mounting force within the range recommended by the semiconductor manufacturer; clamping forces usually range from 800 to 2000 pounds force depending upon the type number.

Installation of an assembly of disc-type semiconductors mounted between two heat dissipators should be done in a manner to permit one heat dissipator to move with respect to the other. Movement will avoid stresses being developed due to thermal expansion, which could damage the semiconductor.

Similarly, when two or more devices are to be operated electrically in parallel, one of the heat dissipators used may be common to all devices. Individual heat dissipators must be provided against the other mounting surfaces of the semiconductors so that the mounting force applied in each case will be independently adjustable.

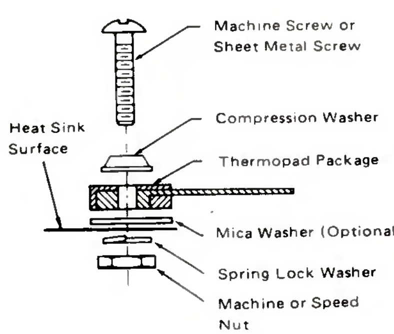
FIGURE 9 — Mounting Details for Disc-Type Semiconductors

Thermopad

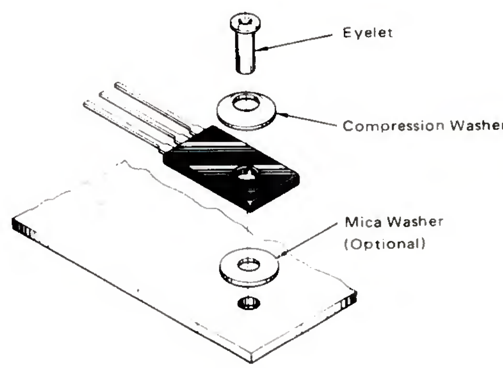
The Motorola Thermopad® plastic power packages have been designed to feature minimum size with no compromise in thermal resistance. This is accomplished by die-bonding the silicon chip on one side of a thin copper sheet; the opposite side is exposed as a mounting surface. The copper sheet has a hole for mounting, i.e., plastic is molded enveloping the chip but leaving the mounting hole open. The benefits of this construction are obtained at the expense of a requirement that strict attention be paid to the mounting procedure. Success in mounting Thermopad devices depends largely upon using a compression washer which provides a controllable pressure across a large bearing surface. Having a small hole with no chamfer and a flat, burr-free, well-finished heat sink are also important requirements.

Several types of fasteners may be used to secure the Thermopad package; machine screws, eyelets, or clips are preferred. With screws or eyelets, a bell compression washer should be used which applies the proper force to the package over a fairly wide range of deflection. Screws should not be tightened with any type of air-driven torque gun or equipment which may cause high impact. Characteristics of the recommended washers are shown in Figure 5.

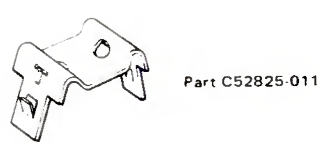
Figure 10 shows details of mounting TO-126 or TO-127 devices. Use of the clip requires that caution be exercised to insure that adequate mounting force is applied. When electrical isolation is required, a bushing inside the mounting hole will insure that the screw threads do not contact the metal base.



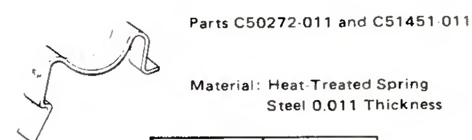
(a) Machine Screw Mounting



(b) Eyelet Mounting

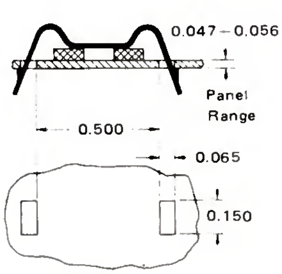


Material: Heat-Treated Spring
Steel 0.011 Thickness

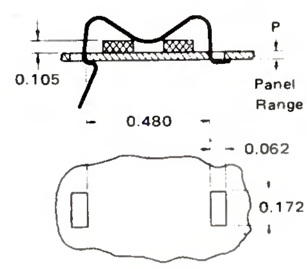


Material: Heat-Treated Spring
Steel 0.011 Thickness

Part	P
C50272-011	0.046-0.055
C51451-011	0.030-0.034



TO-127 Clip



TO-126 Clip

(c) Tinnerman Clips (Eaton Corp.)

FIGURE 10 – Recommended Mounting Arrangements for TO-126 and TO-127 Thermopad Packages

The case 199 Thermopad is not more tolerant of mounting conditions than Case 77 or 90 parts even though the fastener does not bear on the plastic. The screw must not contact the semiconductor base plate as screw heads are not flat enough to apply pressure evenly and may cause warpage of the base plate resulting in die fracture. Procedures for mounting the Case 199 are shown in Figure 11.

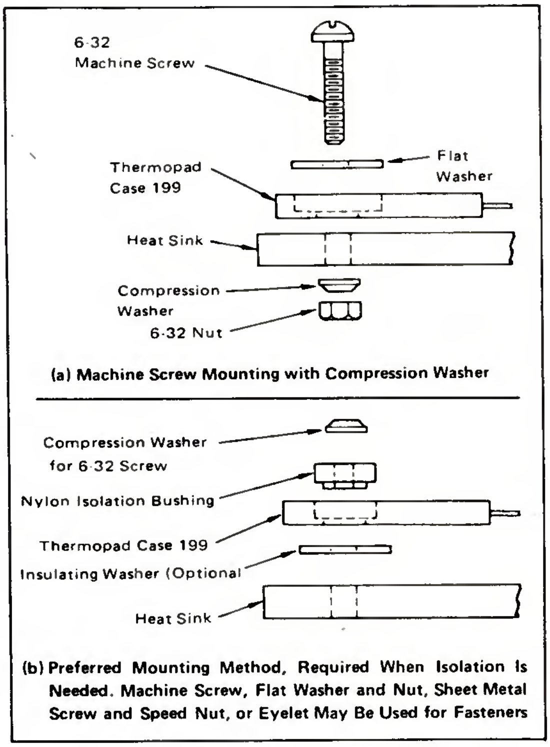


FIGURE 11 — Various Mounting Schemes For the Case 199 Thermopad

(a) shows direct contact with heat sink.
(b) shows technique when isolation is required.

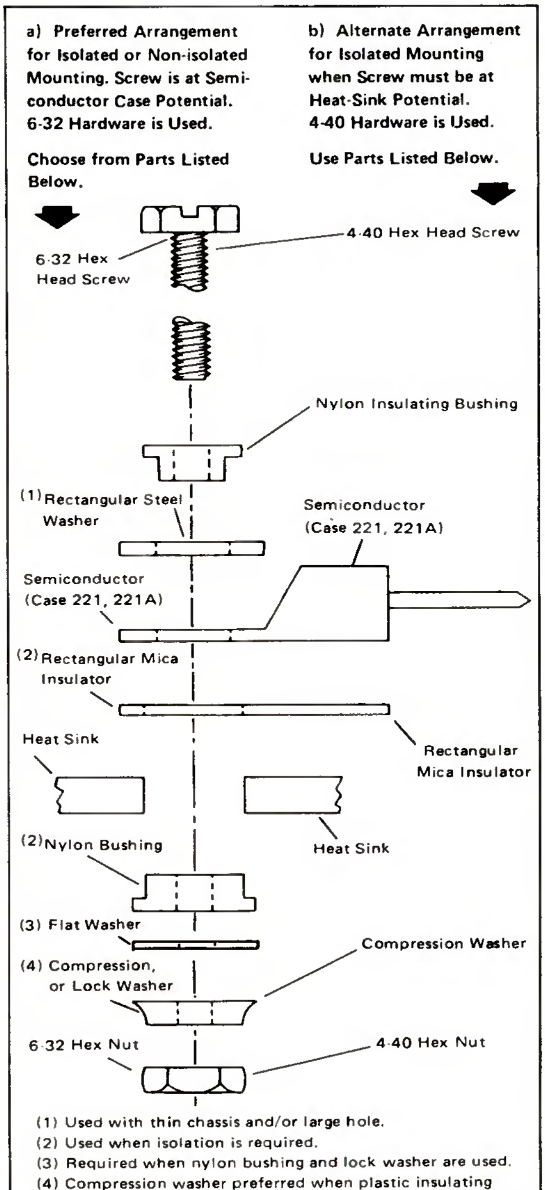
Manual Assembly Should Be Used.

Thermowatt®

The popular TO-220 Thermowatt® package also requires attention to mounting details. Figure 12 shows suggested mounting arrangements and hardware. The rectangular washer shown in Figure 12a is used to minimize distortion of the mounting flange; excessive distortion could cause damage to the semiconductor chip. Use of the washer is only important when the size of the mounting hole exceeds 0.140 inch (6-32 clearance). Larger holes are needed to accommodate insulating bushings when the screw is electrically connected to the case; however, the holes should not be larger than necessary to provide hardware clearance and should never exceed a diameter of 0.250 inch. Flange distortion is also possible if excessive torque is used during mounting. A maximum torque of 8 inch-pounds is suggested when using a 6-32 screw.

Care should be exercised to assure that the tool used to drive the mounting screw never comes in contact with the plastic body during the driving operation. Such contact can result in damage to the plastic body and internal device connections. To minimize this problem, Motorola TO-220 packages have a chamfer on one end. TO-220 packages of other manufacturers may need a spacer or combination spacer and isolation bushing to raise the screw head above the top surface of the plastic.

In situations where the Thermowatt package is making direct contact with the heat sink, an eyelet may be used, provided sharp blows or impact shock is avoided.



(1) Used with thin chassis and/or large hole.
(2) Used when isolation is required.
(3) Required when nylon bushing and lock washer are used.
(4) Compression washer preferred when plastic insulating material is used.

TORQUE REQUIREMENTS

Insulated 0.68 N-M (6 in-lbs) max
Noninsulated 0.9 N-M (8 in-lbs) max

FIGURE 12 — Mounting Arrangements for Thermowatt Packages

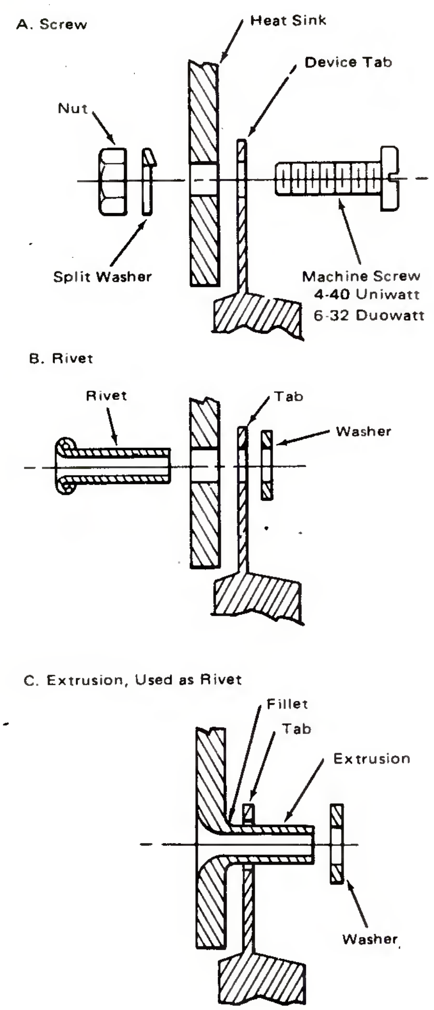
Tab Mount

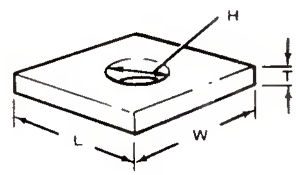
Although the Duowatt® and Uniwatt® packages are designed primarily for use in low-power applications where heat sinks are not required, they can be used to dissipate up to 10 watts if properly mounted to a heat sink. These packages are relatively rugged, since the mounting hole is not close to the die; mounting stresses, therefore, are not easily transmitted to the die.

Figure 13 shows some possible mounting arrangements. An axial load of 300 lbs-force produces minimum contact thermal resistance. This is achieved at 6 in-lbs when a 4-40 machine screw is used. A sheet-metal screw and speed-nut can be substituted for the machine screw and nut, but torque readings are uncertain. The riveting technique should produce 300 lbs-force, using a gradually increasing pressure such as provided by an arbor press.

The extrusion requires a punch press to manufacture; however, it is potentially the least expensive technique. Note that the radius of the fillet must be small enough to allow the tab to lie flat on the heat sink. To utilize an existing chassis and board arrangement on heat sinking, it may be necessary to have the device lie flat on the chassis. In this case, the chassis mounting blocks shown in Figure 13d might be utilized. A possible application is shown in Figure 13e, where a complementary transistor pair is used. Insulated screws and mica insulating washers under the blocks must be used to prevent shorting of the collector circuits of the two transistors. Alternately, an insulated bushing and a #3 screw could be used to secure the packages.

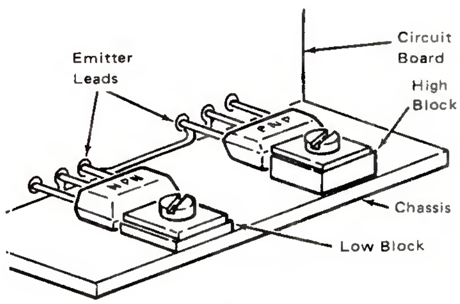
To avoid the use of mounting blocks, a tab-forming option is available. Alternately, some equipment manufacturers have constructed heat sinks with a flat, raised island to permit the package to be flat. Users should not attempt to bend the tab as a cracked die is the probable result.





D. Chassis Mounting Block Details

Block Dimensions					
	H	W	L	T	
				Low Block	High Block
Duowatt	0.140	0.4	0.5	0.07	0.12
Uniwatt	0.113	0.3	0.3	0.06	0.12



E. Chassis Mount Block, Mounting Details

Use Nylon Screws and Mica Insulating Washer to Prevent Shorting the Tabs to the Chassis, and Thus to Each Other.

FIGURE 13 — Methods of Mounting Duowatt and Uniwatt Transistors to a Heat Sink

R.F. Stripline

Besides the usual precautions regarding surface flatness and torque, the stripline package (see Figure 14a) requires attention to the following:

1. The device should never be mounted in such a manner as to place ceramic-to-metal joints in tension.

2. The device should never be mounted in such a manner as to apply force on the strip leads in a vertical direction towards the cap.

3. When the device is mounted in a printed circuit board with the copper stud or flange and BeO portion of the header passing through a hole in the circuit board, adequate clearance must be provided for the BeO to prevent shear forces from being applied to the leads.

4. Some clearance must be allowed between the leads and the circuit board when the device is properly secured to the heat sink.

5. The device should be properly secured into the heat sinks before the device leads are attached into the circuit.

6. The leads must not be used to prevent device rotation on stud type devices during stud torque application. A wrench flat is provided for this purpose.

Most of the considerations listed above are designed to prevent tension at the metal-ceramic interfaces on the SOE package. Improper mechanical design can lead to application of stresses to these joints resulting in device destruction. Three joints are considered: the cap to the BeO disc, the leads to the disc, and the stud or flange to the disc.

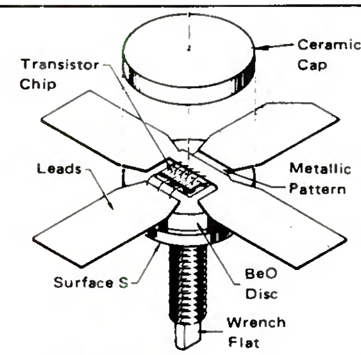
The joint between the ceramic cap and the BeO ceramic disc is composed of a material which loses strength above 175°C. While the strength of the material returns upon cooling, any force applied to the cap at high temperature may result in failure of the cap to ceramic joint.

Figure 14b shows a cross-section of a printed circuit board and heat-sink assembly for mounting a stud type stripline device. H is the distance from the top surface of the printed circuit board to the D-flat heat-sink surface. If H is less than the minimum distance from the bottom of the lead material to the mounting surface of the package, there is no possibility of tensile forces in the copper stud – BeO ceramic joint. If, however, H is greater than the package dimension, considerable force is applied to the cap to BeO joint and the BeO to stud joint. Two occurances are possible at this point. The first is a cap joint failure when the structure is heated, as might occur during the lead-soldering operation; while the second is BeO to stud failure if the force generated is high enough. Lack of contact between the device and the heat-sink surface will occur as the differences between H and the package dimension becomes larger, this may result in device failure as power is applied.

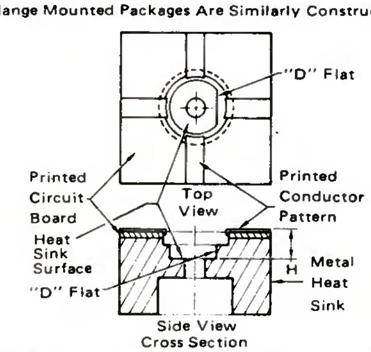
Figure 14c shows a typical mounting technique for flange-type stripline transistors. Again, H is defined as the distance from the top of the printed circuit board to the heat-sink surface. If distance H is less than the minimum distance from the bottom of transistor lead to the bottom surface of the flange, tensile forces at the various joints in the package are avoided. However, if distance H exceeds the package dimension, problems similar to those discussed for the stud type devices can occur. Because of the ability of the copper flange to bend under the types of loads encountered when the mounting screws are tightened, permanent deformation of the flange may result. Corrective action after the flange has been bent will not necessarily insure proper thermal contact with the heat sink.

The flange surface as supplied with Motorola transistors is either flat or slightly convex. It is important that the mating heat-sink surface also be flat or slightly convex to provide the best contact when the device is properly secured.

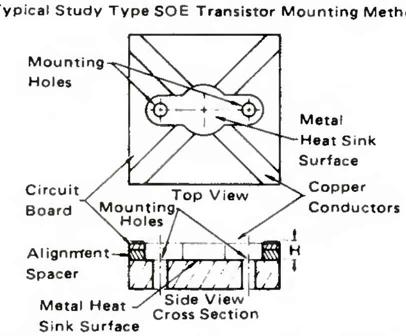
Since the flange may be permanently deformed during mounting, the device should not be dismounted and remounted in another position, without checking the flatness. The flange may be resurfaced using emery cloth mounted on a large, flat block. While this removes the gold- or nickel-plating, the thin layer of copper oxide which rapidly forms causes an insignificant increase in thermal resistance, although corrosion may occur.



(a) Component Parts of a Stud Mount Stripline Package. Flange Mounted Packages Are Similarly Constructed



(b) Typical Study Type SOE Transistor Mounting Methods



(c) Flange Type SOA Transistor Mounting Method

FIGURE 14 – Mounting Details for SOE Transistors

FREE AIR AND SOCKET MOUNTING

In applications where average power dissipation is of the order of a watt or so, power semiconductors may be mounted with little or no heat-sinking. The leads of the various metal power packages are not designed to support the packages; their cases must be firmly supported to avoid the possibility of cracked glass-to-metal seals around the leads. The plastic packages may be supported by their leads in applications where high shock and vibration stresses are not encountered and where no heat sink is used. The leads should be as short as possible to increase vibration resistance and reduce thermal resistance.

In many situations, because its leads are fairly heavy, the TO-127 package has supported a small heat sink; however, no definitive data is available. When using a small heat sink, it is good practice to have the sink rigidly mounted such that the sink or the board is providing total support for the semiconductor. Two possible arrangements are shown in Figure 15. The arrangement of part (a) could be used with any plastic package, but the scheme of part (b) is more practical with Case 77 or Case 90 Thermopad devices. With the other package types, mounting the transistor on top of the heat sink is more practical.

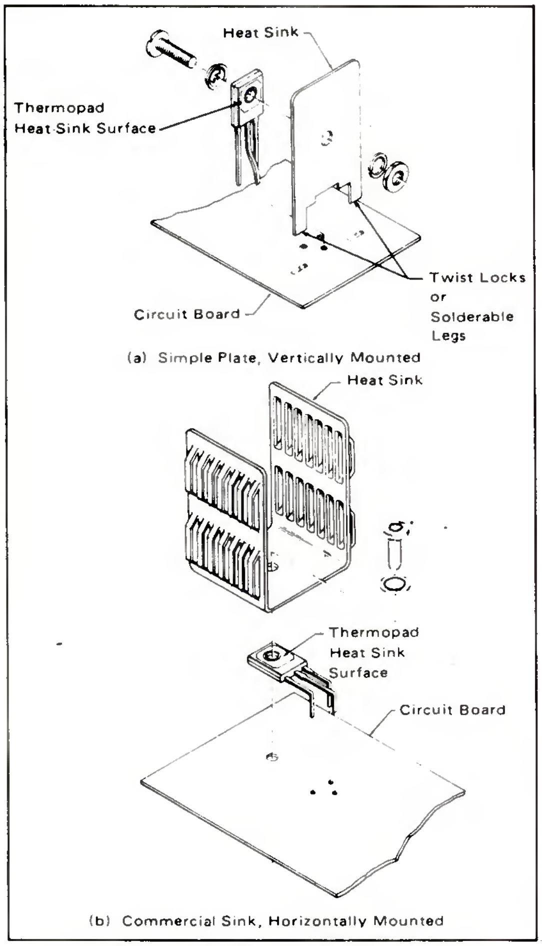


FIGURE 15 — Methods of Using Small Heat Sinks With Plastic Semiconductor Packages

In certain situations, in particular where semiconductor testing is required, sockets are desirable. Manufacturers have provided sockets for all the packages available from Motorola. The user is urged to consult manufacturers' catalogs for specific details.

HANDLING PINS, LEADS, AND TABS

The pins and lugs of metal-packaged devices are not designed for any bending or stress. If abused, the glass-to-metal seals could crack. Wires may be attached using sockets, crimp connectors, or solder, provided the data-sheet ratings are observed.

The leads and tabs of the plastic packages are more flexible and can be reshaped, although this is not a recommended procedure for users to do. In some cases, a heat sink can be chosen which makes lead-bending unnecessary. Numerous lead- and tab-forming options are available from Motorola. Preformed leads remove the risk of device damage caused by bending from the users.

If, however, lead-bending is done by the user, several basic considerations should be observed. When bending the lead, support must be placed between the point of bending and the package. For forming small quantitites of units, a pair of pliers may be used to clamp the leads at the case, while bending with the fingers or another pair of pliers. For production quantities, a suitable fixture should be made.

The following rules should be observed to avoid damage to the package.

1. A lead-bend radius greater than 1/16 inch is advisable for TO-126, 1/10 inch for TO-127 and Case 199, and 1/32 inch for TO-220.
2. No twisting of leads should be done at the case.
3. No axial motion of the lead should be allowed with respect to the case.

The leads of plastic packages are not designed to withstand excessive axial pull. Force in this direction greater than 4 pounds may result in permanent damage to the device. If the mounting arrangement imposes axial stress on the leads, a condition which may be caused by thermal cycling, some method of strain relief should be devised. An acceptable lead-forming method that provides this relief is to incorporate an S-bend into the lead. Wire-wrapping of the leads is permissible, provided that the lead is restrained between the plastic case and the point of the wrapping. The leads may be soldered; the maximum soldering temperature, however, must not exceed 275°C and must be applied for not more than 5 seconds at a distance greater than 1/8 inch from the plastic case. When wires are used for connections, care should be exercised to assure that movement of the wire does not cause movement of the lead at the lead-to-plastic junctions.

CLEANING CIRCUIT BOARDS

It is important that any solvents or cleaning chemicals used in the process of degreasing or flux removal do not affect the reliability of the devices.

Alcohol and unchlorinated Freon solvents are generally satisfactory for use with plastic devices, since they do not damage the package. Hydrocarbons such as gasoline may cause the encapsulant to swell, possibly damaging the transistor die. Likewise, chlorinated Freon solvents are unsuitable, since they may cause the outer package to dissolve and swell.

When using an ultrasonic cleaner for cleaning circuit boards, care should be taken with regard to ultrasonic energy and time of application. This is particularly true if the packages are free-standing without support.

THERMAL SYSTEM EVALUATION

Assuming that a suitable method of mounting the semiconductor without incurring damage has been achieved, it is important to ascertain whether the junction temperature is within bounds.

In applications where the power dissipated in the semiconductor consists of pulses at a low duty cycle, the instantaneous or peak junction temperature, not average temperature, may be the limiting condition. In this case, use must be made of transient thermal resistance data. For a full explanation of its use, see Motorola Application Note, AN-569.

Other applications, notably RF power amplifiers or switches driving highly reactive loads, may create severe current crowding conditions which render the traditional concepts of thermal resistance or transient thermal impedance invalid. In this case, transistor safe operating area or thyristor di/dt limits, as applicable, must be observed.

Fortunately, in many applications, a calculation of the average junction temperature is sufficient. It is based on the concept of thermal resistance between the junction and a temperature reference point on the case. (See Appendix A.) A fine wire thermocouple should be used, such as #32AWG, to determine case temperature. Average operating junction temperature can be computed from the following equation:

$$T_J = T_C + R_{\theta JC} \times P_D$$

where T_J = junction temperature (^oC)
T_C = case temperature (^oC)
$R_{\theta JC}$ = thermal resistance junction-to-case as specified on the data sheet ($^oC/W$)
P_D = power dissipiated in the device (W).

The difficulty in applying the equation often lies in determining the power dissipation. Two commonly used empirical methods are graphical integration and substitution.

Graphical Integration

Graphical integration may be performed by taking oscilloscope pictures of a complete cycle of the voltage and current waveforms, using a limit device. The pictures should be taken with the temperature stabilized. Corresponding points are then read from each photo at a suitable number of time increments. Each pair of voltage and current values are multiplied together to give instantaneous values of power. The results are plotted on linear graph paper, the number of squares within the curve counted, and the total divided by the number of squares along the time axis. The quotient is the average power dissipation.

Substitution

This method is based upon substituting an easily measurable, smooth dc source for a complex waveform. A switching arrangement is provided which allows operating the load with the device under test, until it stabilizes in temperature. Case temperature is monitored. By throwing the switch to the "test" position, the device under test is connected to a dc power supply, while another pole of the switch supplies the normal power to the load to keep it operating at full power level. The dc supply is adjusted so that the semiconductor case temperature remains approximately constant when the switch is thrown to each position for about 10 seconds. The dc voltage and current values are multiplied together to obtain average power. It is generally necessary that a Kelvin connection be used for the device voltage measurement.

APPENDIX A

THERMAL RESISTANCE CONCEPTS

The basic equation for heat transfer under steady-state conditions is generally written as:

$$q = hA\Delta T \qquad (1)$$

where q = rate of heat transfer or power dissipation (P_D),
h = heat transfer cofficient,
A = area involved in heat transfer,
ΔT = temperature difference between regions of heat transfer.

However, electrical engineers generally find it easier to work in terms of thermal resistance, defined as the ratio of temperature to power. From Equation 1, thermal resistance, R_θ, is

$$R_\theta = \Delta T/q = 1/hA \qquad (2)$$

The coefficient (h) depends upon the heat transfer mechanism used and various factors involved in that particular mechanism.

An analogy between Equation (2) and Ohm's Law is often made to form models of heat flow. Note that ΔT could be thought of as a voltage; thermal resistance corresponds to electrical resistance (R); and, power (q) is analogous to current (I). This gives rise to a basic thermal resistance model for a semiconductor as indicated by Figure A1.

The equivalent electrical circuit may be analyzed by using Kirchoff's Law and the following equation results:

$$T_J = P_D(R_{\theta JC} + R_{\theta CS} + R_{\theta SA}) + T_A \qquad (3)$$

where T_J = junction temperature,
P_D = power dissipation,
$R_{\theta JC}$ = semiconductor thermal resistance (junction to case),
$R_{\theta CS}$ = interface thermal resistance (case to heat sink),
$R_{\theta SA}$ = heat sink thermal resistance (heat sink to ambient),
T_A = ambient temperature.

The thermal resistance junction to ambient is the sum of the individual components. Each component must be minimized if the lowest junction temperature is to result.

The value for the interface thermal resistance, $R_{\theta CS}$, is affected by the mounting procedure and may be significant compared to the other thermal-resistance terms.

The thermal resistance of the heat sink is not constant; it decreases as ambient temperature increases and is affected by orientation of the sink. The thermal resistance of the semiconductor is also variable; it is a function of biasing and temperature. In some applications such as in RF power amplifiers and short-pulse applications, the concept may be invalid because of localized heating in the semiconductor chip.

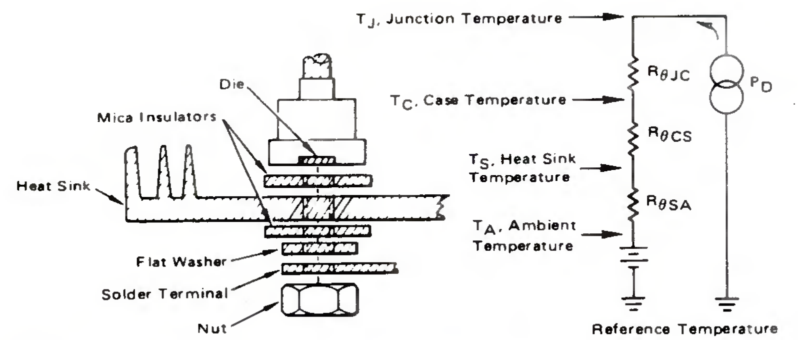


FIGURE A1 – Basic Thermal Resistance Model Showing Thermal to Electrical Analogy for a Semiconductor

APPENDIX B
SOURCES OF ACCESSORIES

Manufacturer	Joint Compound	Insulators						Heat Sinks					
		BeO	AlO_2	Anodize	Mica	Plastic Film	Silicone Rubber	Stud	Flange	Disc	Thermowatt	Uni/Duo Watt	RF Stripline
Aavid Eng.	Ther-o-link 1000	–	–	–	–	–	–	X	X	–	X	–	–
AHAM	–	–	–	–	–	–	–	X	X	–	X	–	–
Astrodyne	#829	–	–	–	–	–	–	X	X	X	X	X	–
Delbert Blinn	–	X	–	X	X	X	X	X	X	–	–	–	–
IERC	Thermate	–	–	–	–	–	–	X	X	–	X	X	X
Staver	–	–	–	–	–	–	–	X	X	–	X	X	X
Thermalloy	Thermacote	X	X	X	–	X	–	X	X	X	X	X	X
Tor	TJC	X	–	X	X	X	–	X	X	–	X	–	–
Tran-tec	XL500	X	–	–	–	X	X	X	X	X	X	X	X
Wakefield Eng.	Type 120	X	–	X	–	–	–	X	X	X	X	X	–
Wei Corp.	–	–	–	–	–	–	–	X	X	–	–	–	–

Other sources for Joint Compounds: Dow Corning, Type 340
Emerson & Cuming, Eccoshield – SO (Electrically Conducting)
Emerson & Cuming, Eccotherm – TC-4 (Electrically Insulating)

APPENDIX B
SUPPLIERS ADDRESSES

Aavid Engineering, Inc., 30 Cook Court, Laconia, New Hampshire 03246 (603) 524-4443

AHAM Heat Sinks, 27901 Front Street, Rancho, California 92390 (714) 676-4151

Astrodyne, Inc., 353 Middlesex Avenue, Wilmington, Massachusetts 01887 (617) 272-3850

Delbert Blinn Company, P.O. Box 2007, Pomona, California 91766 (714) 623-1257

Dow Corning, Savage Road Building, Midland, Michigan 48640 (517) 636-8000

Eaton Corporation, Engineered Fasteners Division, Tinnerman Plant, P.O. Box 6688, Cleveland, Ohio 44101 (216) 523-5327

Emerson & Cuming, Inc., Dielectric Materials Division, 869 Washington Street, Canton, Massachusetts 02021 (617) 828-3300

International Electronics Research Corporation, 135 West Magnolia Boulevard, Burbank, California 91502 (213) 849-2481

The Staver Company, Inc., 41-51 North Saxon Avenue, Bay Shore, Long Island, New York 11706 (516) 666-8000

Thermalloy, Inc., P.O. Box 34829, 2021 West Valley View Lane, Dallas, Texas 75234 (214) 243-4321

Tor Corporation, 14715 Arminta Street, Van Nuys, California 91402 (213) 786-6524

Tran-tec Corporation, P.O. Box 1044, Columbus, Nebraska 68601 (402) 564-2748

Wakefield Engineering, Inc., Wakefield, Massachusetts 01880 (617) 245-5900

Wei Corporation, 1405 South Village Way, Santa Ana, California 92705 (614) 834-9333

MOTOROLA Semiconductor Products Inc.

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11120 PRINTED IN USA 2-78 IMPERIAL LITHO B69629 10M

AN-778

COMMUNICATIONS TRANSISTOR CORPORATION

CD2315

GENERAL DESCRIPTION – The CD2315 is a 28 volt, VHF device specifically designed for very high peak power.

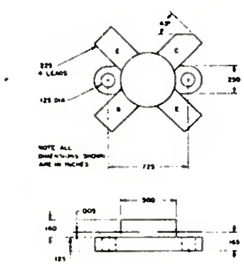
Maximum Power Dissipation (Note 1)
Total Power Dissipation at 25° C Case Temperature — 250W

Maximum Voltage and Current

BV_{CES}	Collector to Emitter Voltage	60V
BV_{EBO}	Emitter to Base Voltage	4V
I_C	Collector Current	12A

PACKAGE

1/2" FLANGE



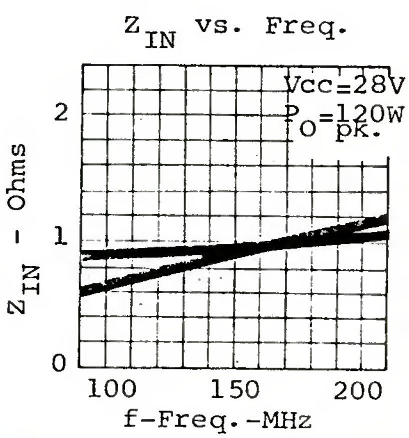
ELECTRICAL CHARACTERISTICS (25° C unless otherwise specified)

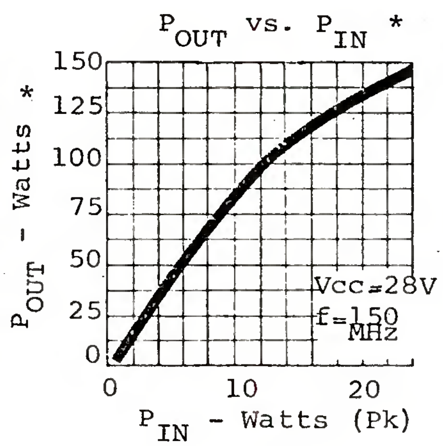
SYMBOL	CHARACTERISTICS	MIN.	TYP.	MAX.	UNITS	TEST CONDITIONS
P_{OUT}	Power Output	120			WATTS	f = 150 MHz Vcc = 28V *
P_{IN}	Power Input (At rated Power Out)			20	WATTS	f = 150 MHz Vcc = 28V *
η	Collector Efficiency (At rated Power Out)		65		%	f = 150 MHz Vcc = 28V
Z_{IN}	Series Input Impedance		1.0+j0.9		OHMS	At rated output power and frequency
C_{OB}	Collector to Base Capacitance (f = 1.0 MHz)		145		pF	V_{CB} = 28 V, I_E = 0
BV_{EBO}	Emitter to Base Voltage	4			VOLTS	I_E = 5 mA
BV_{CES}	Collector to Emitter	60			VOLTS	I_C = 100 mA
LV_{CEO}		30			Volts	Ic = 50 mA

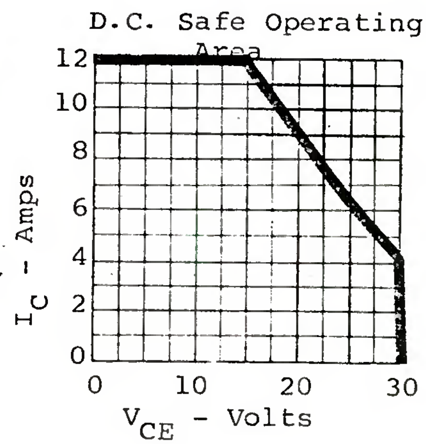
* Peak Power– 1 KHz, 50% D.C.

NOTES:

1. This rating gives a maximum junction temperature of 200° C with junction to case thermal resistance of .7° C/watt.







COMMUNICATIONS TRANSISTOR CORPORATION
301 Industrial Way, San Carlos, California 94070

An Affiliate of Eimac/Varian
(415) 591-8921 TWX 910-376-4893

LINCOLN MOTORS®

IM-257-A

OPERATING MANUAL

Lincguard™ • TEFC • Multiguard® — 143T Thru 445T

RECEIVING

Uncrate the motor and check for any damage. Turn the shaft by hand to be certain that it rotates freely. Claims for any damage done in shipment must be made by the purchaser against the transportation company.

SAFETY DEPENDS ON EVERYONE

Lincoln motors are designed and built with safety in mind. However, your overall safety can be increased by thoughtful action on your part. Carefully read and follow the safety precautions outlined below plus all the installation, operating and maintenance instructions in this manual. Most importantly, before you act, make certain it is safe.

SAFETY PRECAUTIONS

The high voltage and rotating parts associated with motor applications can cause serious injury. It is important to observe and follow safety precautions to protect personnel from such injury. Personnel should be instructed to:

1. Have all installation, maintenance and repair work performed only by qualified people.
2. Disconnect and lock out all power sources before doing any work on the equipment.
3. Follow the procedures outlined under 'Caution When Using Lift Hooks' whenever the equipment is lifted.
4. Make the electrical installation in accordance with the National Electrical Code and local codes.
5. Properly ground the equipment in accordance with the National Electrical Code.
6. Be sure shaft key is fully captive before unit is energized.
7. Keep hands, hair, clothing and tools away from all moving parts when operating or repairing equipment.
8. Provide proper safeguards for personnel to prevent contact with rotating parts.

It is strongly recommended that all concerned personnel be familiar with and adhere to the contents of NEMA MG-2, "Safety Standard For Construction and Guide For Selection, Installation and Use of Electric Motors and Generators."

CAUTION When Using Lift Hooks

Do not use the lift hook on the motor to lift the motor along with additional equipment, such as pumps, compressors or other driven machinery. In the case of assemblies on a common base, do not lift with the motor lift hook but rather use a sling around the base or the lifting means provided on the base. In all cases, take care to assure lifting only in the direction intended in the design of the lifting means. Also, be careful to avoid hazardous overloads due to deceleration, acceleration or shock forces.

MECHANICAL MOUNTING

Mount the motor to a firm foundation being sure that the motor rests evenly on all feet. Shims may be required when precise alignment is required.

Use a properly designed and installed coupling system between the motor shaft and load (see "Maintenance" on page 2).

143T thru 256T (Aluminum) Frame Sizes

Ball bearing motors of this type may be mounted in any position. The motors have drain holes suitable for standard horizontal and vertical mountings. Other mounting positions may require either rotation of the end brackets or drilling additional holes.

To mount the conduit box, place the inner gasket and the box in place on the motor with the conduit knock-out in the desired location. Install and tighten the two mounting studs. Install the input power conduit. After connecting and insulating the leads (see "Electrical Connections") place the outer gasket and cover on the conduit box and tighten the acorn nuts.

284T thru 445T (Steel) Frame Sizes

Ball bearing motors of this type may be mounted in any position. To maintain the best drip-proof protection, the end brackets and terminal box can be rotated to any of four positions 90° apart. Since the windings of the Multiguard® motors are imbedded in a moisture resistant plastic covering, this is not always necessary. When ceiling mounted, a drain hole in the top of the frame is sometimes desirable.

Before installing the conduit box on **Multiguard** motors, slip the sealing tube over the motor leads and against the winding encapsulation. Install the rubber washer over the end of the tube and against the outside of the frame. When the conduit box is mounted the tube and washer are compressed to protect the leads and the inside of the conduit box from contaminants.

Before installing the conduit box on **Lincguard** motors, slip the rubber washer over the motor leads and against the outside of the frame. When the conduit box is mounted the washer is compressed to restrict the entry of contaminants into the conduit box.

Slip the **conduit box** over the motor leads and against the frame. Rotate it until the conduit knockout is in the desired location. Install and tighten the two self-tapping screws to hold the box to the frame. Install the input power conduit. After connecting and insulating the input leads (see "Electrical Connections") place the cover on the box then install and tighten the screws supplied.

ELECTRICAL CONNECTIONS

Motor Voltage vs. Power System Voltage

Motor should be applied to voltage systems per the following:

NEMA Motor Nameplate Voltage	Nominal System Voltage
200	208
230	240
460	480
575	600

Do not apply: 208 volt motors on 230 volt systems
230 volt motors on 208 volt systems

Dual Input Voltage Connection

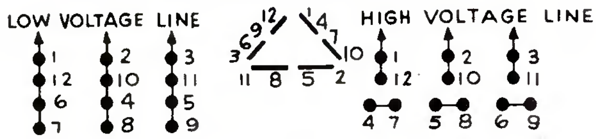
Some Lincoln motors are wired for operation on either of two input voltages. Proper connection of the motor leads for either voltage is shown on the motor nameplate. "LOW VOLTAGE" on the nameplate shows the wiring for the lower of the two possible input voltages. Each motor lead is tagged with the proper lead number.

Connection diagrams for standard dual voltage motors for across the line and auto transformer starting are reproduced below. See page 3 for Part Winding Start and Star-Delta Start connection diagrams.

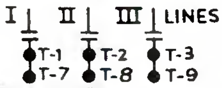
60 Hertz Motors

143T — 256T Motors: 9 Leads Y Connected

284T — 405T Motors: 12 Leads Δ Connected



324T — 445T Motors: Full Winding Start, 6 Leads



Y-Δ Motors

Connection to Power Supply

Proper branch circuit supply to a motor should include a disconnect switch, short circuit current fuse or breaker protection, motor starter (controller) and overload relay protection. Each of these should be properly sized and installed per the National Electrical Code and local codes.

Unless specifically exempted by the National Electrical Code or local codes ground the motor as specified in the codes. On 143T thru 256T (Aluminum) Frames a grounding screw and lug are provided for this purpose. A tapped hole for this screw identified by ground symbol ⏚ is located in the frame and is accessible inside the mounted conduit box. On 284T thru 445T [steel] frames one of the conduit box mounting screws which is accessible inside the mounted conduit box is used for grounding purposes. It is identified by ground symbol ⏚.

Short circuit current fuses or breakers are for the protection of the branch circuit. Starter or controller overload relays are for the protection of the motor.

Overload Relays and Trip Timer

The National Electrical code specifies an overload relay in each phase of the three phase power supply to protect the motor against excessive input current caused by the following:

Overloading — Overloading a motor causes excessive input current which increases motor temperatures, shortens stator life and can cause an overload burnout.

Voltage Variation (From Nameplate) — Excessively high voltage increases idle current by 25 to 50%. Excessively low voltage increases load current by 10% or more.

Voltage Unbalance (Between Phases) — A voltage unbalance of 3.5% can result in a current unbalance and temperature increase of 25%.

Single Phasing — When starting, single phased motors develop no torque and draw high current. Single phasing under load approximately doubles the load current.

Overload relays should be sized per the instructions of the starter manufacturer. In general, sizing of overload relays is based on a percent of motor nameplate full load current depending on the type of starter.

Under normal conditions, overload relays provide protection between 110 and 120% of their current rating. No extra allowance for service factor is necessary.

On across the line starting, the trip time for properly sized overload relays should be approximately 15 seconds under locked rotor current conditions of 600% full load current. If the starting time goes beyond 15 seconds, the overload relay should disconnect the motor from the line to prevent motor stator overload burnout. Oversizing the overload relay is NOT the way to eliminate excessive tripping. Eliminate excessive voltage drop, reduce starting time and properly sizing the motor are correct answers.

OPERATION

After checking that the shaft key is secure, operate the motor free of load and check the direction of rotation. If the motor rotates in the wrong direction, interchange any two line leads. Couple the motor to its load and operate for a minimum of one hour. During this period, check for any unusual noise or thermal conditions. Check the actual operating current to be sure that the nameplate current times service factor is not exceeded for steady continuous loads. See "Maintenance" below for possible causes of unusual noise or heat.

LUBRICATION

Your motor is equipped with double-shield ball bearings* having sufficient grease to last indefinitely under normal service. Where the motor is used constantly in dirty, wet or corrosive atmospheres, it is advisable to add one quarter ounce of grease per bearing every three months. Use a good quality rust inhibited polyurea based grease, such as Chevron SRI.

When greasing the bearings, keep all dirt out of the area. Wipe the fittings completely clean and use clean equipment. More bearing failures are caused by dirt introduced during greasing than from insufficient grease.

*The blower end bearings of 143T and 145T sizes are sealed bearings and need no greasing.

MAINTENANCE

Periodically inspect your motor for excessive dirt, friction or vibration. Dust may be blown from inaccessible locations using compressed air. Keep the ventilation openings clear to allow free passage of air. Be sure the drain holes in the motors are kept open and the shaft slinger is positioned against the end bracket.

Grease or oil can be wiped up using a petroleum solvent.

Overheating of the bearing caused by excessive friction is usually caused by one of the following factors:

1. Bent shaft.
2. Excessive belt tension.
3. Excessive end or side thrust from the gearing, flexible coupling, etc.
4. Poor alignment.

Damaging vibrations can be caused by loose motor mountings, by misalignment resulting from the settling or distortion of the foundation, or it may be transmitted from the driven machine. Vibration may also be caused by excessive belt or chain tension.

GUARANTEE

The Lincoln Electric Company, the Seller, warrants all new motors and accessories thereof against defects in workmanship and material for a period of one year from date of shipment, provided the equipment has been properly cared for, and operated under normal conditions.

If the Buyer gives the Seller written notice of any defects in equipment within any period of warranty and the Seller's inspection confirms the existence of such defects, then the Seller shall correct the defect or defects at its option, either by repair or replacement F.O.B. its own factory or other place as designated by the Seller. The remedy provided Buyer herein for breach of Seller's warranty shall be exclusive.

No expense, liability or responsibility will be assumed by the Seller for repairs made outside of the Seller's factory without written authority from the Seller.

The Seller shall not be liable for any consequential damages in case of any failure to meet the conditions of any warranty. The liability of the Seller arising out of the supplying of said equipment or its use by the Buyer, whether on warranties or otherwise, shall not in any case exceed the cost of correcting defects in the equipment in accordance with the above guarantee. Upon the expiration of any period of warranty, all such liability shall terminate.

The foregoing guarantees and remedies are exclusive and except as above set forth there are no guarantees or warranties with respect to accessories or equipment, either express or arising by operation of law or trade usage or otherwise implied, including without limitation the warranty of merchantability, all such warranties being waived by the Buyer.

Lincoln Motors with Standard Windings are suitable for PWS or Y Δ Starting per the following table:

Table II

MOTOR			Typical 60 Hertz Winding Voltage	Number Leads Out	Suitability of Standard* Motors For PWS	PWS Connection Diagram Number (pg. 4)	Suitability of Standard † Motors for Y Δ On Either Voltage	Y Δ Connection Diagram Number (pg. 4)
HP	Speed RPM	T Frame						
15- 20	1200	284T-286T	230/460	12	No**	–	Yes	Y Δ – A
25- 50	1200	324T-365T	230/460	12	Yes – 230V only	PWS – A	Yes	Y Δ – A
60- 75	1200	404T-405T	230/460	12	No*	*	Yes	Y Δ – A
25-125	1800	284T-405T	230/460	12	No*	*	Yes	Y Δ – A
30-150	3600	284T-405T	230/460	12	No**	–	Yes	Y Δ – A
100-125	1200	444T-445T	460	6	Yes	PWS – B	No†	†
150-200	1800	444T-445T	460	6	Yes	PWS – B	No†	†

. Lincoln Motor Bulletin D2T provides complete information about the various starting means applicable to Lincoln motors in current production.

* When part winding starting is required and standard motors are not suitable per Table II, single voltage motors specially wound for PWS at that voltage must be ordered. They will have 6 leads out and are connected per diagram PWS-B.

** 284T and 286T frame sizes and 3600 RPM motors of all frame sizes are not available for PWS.

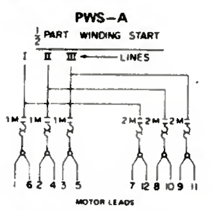
† When star-delta starting is required and standard motors are not suitable, single voltage motors specially wound for star-delta starting at that voltage must be ordered. They will have 6 leads out and are to be connected per diagram Y Δ – B.

Motors wound for 200/400 volts (and other dual voltage systems where the high voltage is twice the low voltage) have the same PWS or Y Δ starting characteristics as the 230/460 volt designs.

PART WINDING START CONNECTIONS

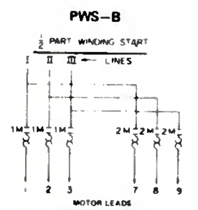
PWS–A

Use for dual voltage, Δ connected, 12 lead motors suitable for PWS. Connect for lower voltage PWS operation only.



PWS–B

Use for single voltage 6 lead motors suitable for PWS.



1M-Closed at start and for run. 2M-Run only contactor.

Note: These diagrams apply to current Model Lincoln Motors. For earlier motors contact the factory giving specific Lincoln code numbers from the nameplate.
Overload relay protection is required by the National Electrical Code. Consult the starter manufacturer for specifications.

BEARING SIZE TABLE

Frame	Shaft Extension End	Opposite Shaft Extension End
140T	205	203*
180T	207	205
210T	208	206
250T	309	307
280T	310	309
320T	311	309
360T	313	311
400T	315	313
440T	318*	315

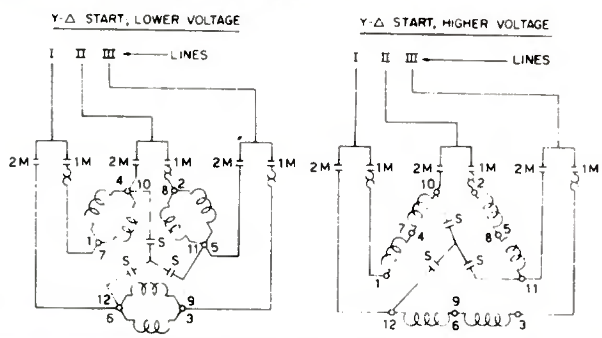
* All bearings except the 318 are single-row radial deep-groove type ball bearings. The 318 size is a single-row maximum capacity type ball bearing. All are double shielded except the 203 size which is double sealed. Frame 280T through 405T double shaft extension motors have both bearings of the size listed under "Shaft Extension End."

Original Lincoln quality is maintained by replacement per Lincoln parts lists P-90-A and P-99-A. This table is provided as information only.

STAR-DELTA (Y-Δ) CONNECTIONS

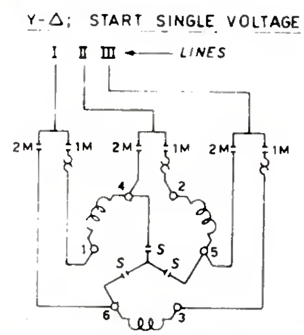
Y Δ–A

Use for dual voltage 12 lead motors suitable for Y-Δ starting for operation on either voltage.



Y Δ–B

Use for single voltage 6 lead motors suitable for Y-Δ starting.



Note: Motor to contactor lines must have current carrying capacity of at least 60% of motor's rated full load current.

Overload relay protection is required by the National Electrical Code. Consult the starter manufacturer for specifications.

Contactors:
S – Start Only Contactors
2M – Run Only Contactor
1M – Closed at Start and for Run.

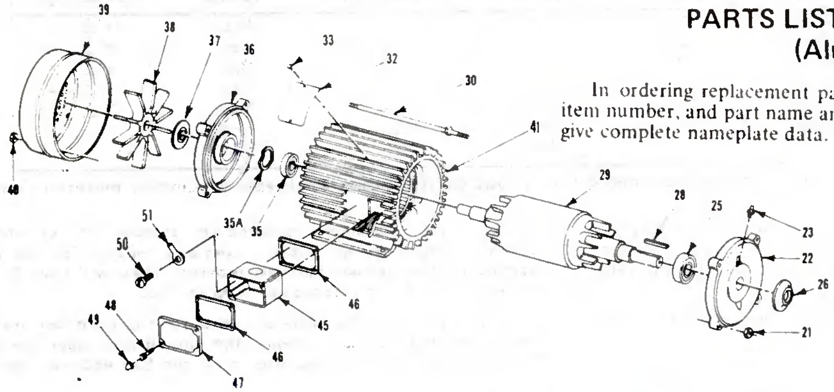
The above diagrams apply to current model Lincoln motors. For other models contact the factory giving specific Lincoln code numbers from the nameplate.

HOW TO ORDER REPLACEMENT PARTS

All parts should be ordered from Authorized Field Service Shops or branch offices. The "Field Service Directory" listing all Authorized Field Service Shops geographically is available upon request. These shops stock GENUINE replacement parts and have factory trained men to service your machine.

PARTS LIST P-90-A: 143 Thru 256T (Aluminum Frame)

In ordering replacement parts give motor code, frame size, part item number, and part name and description. When ordering a stator give complete nameplate data.

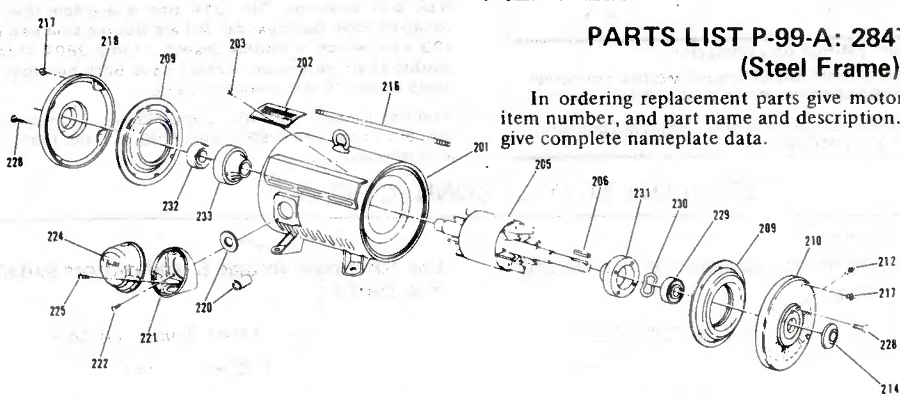


ITEM	PART NAME AND DESCRIPTION	NO. REQ'D.
21	Nut	4
22	End Bracket (Shaft End)	1
23	Grease Fitting	2
25	Bearing (Shaft End)	1
26	Rubber Slinger	1
28	Key	1
29	Rotor	1
30	Through Bolt	4
32	Nameplate	1
33	Drive Screw, Nameplate Mounting	1
35	Bearing (Blower End)	1
35A	Spring Washer (Blower End)	2

ITEM	PART NAME AND DESCRIPTION	NO. REQ'D.
36	End Bracket (Blind End)	1
37	Rubber Slinger - except 143T & 145T	1
38	Fan	1
39	Fan Shroud	1
40	Nut	4
41	Stator	1
45	Conduit Box Kit, Include Items 45-51	1
46	Conduit Box Gasket	2
47	Conduit Box Cover	1
48	Stud, Conduit Box Mounting	2
49	Acorn Nut	2
50	Grounding Screw	1
51	Grounding Lug	1

PARTS LIST P-99-A: 284T Thru 445T (Steel Frame)

In ordering replacement parts give motor code, frame size, part item number, and part name and description. When ordering a stator give complete nameplate data.



ITEM	PART NAME AND DESCRIPTION	NO. REQ'D.
201	Stator	1
202	Nameplate	1
203	Drive Screw, Nameplate Mounting	2
205	Rotor	1
206	Key	1
209	Air Baffle	2
210	End Bracket, Shaft End	1
212	Grease Fitting	2
214	Slinger	1
216	Through Bolts	4
217	Hex Nuts	8
218	End Bracket, Opposite End	

ITEM	PART NAME AND DESCRIPTION	NO. REQ'D.
221	Conduit Box Kit, Includes Items 220-225	1
220	Washer, Box to Frame, Lincguard & Multiguard	1
220	Sleeve, Box to Stator, Multiguard Only	1
222	Self Tapping Screw, Conduit Box to Frames	2
224	Conduit Box Cover	1
225	Screws, Cover Mounting	2
228	Hex Head Bolts	6
229	Bearing, Shaft End	1
230	Thrust Washer	1
231	Cast Iron Cartridges, Shaft End	1
232	Bearing, Opposite End	1
233	Cast Iron Cartridge, Opposite End	1

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Ram

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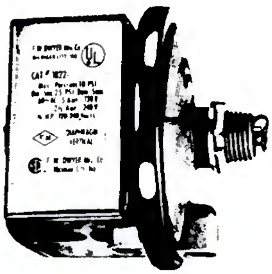
Litho in U.S.A.

BULLETIN E-53

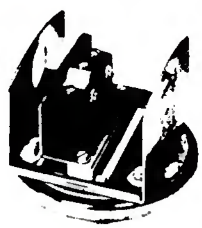
SERIES 1800*

Low Differential Pressure Switches for General Industrial Service

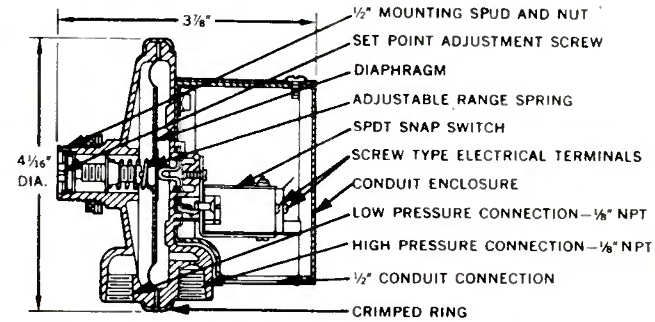
Compact, economically priced switches in 8 standard ranges. Set points from 0.15" to 80" W.C. Repetitive accuracy within 2%. U.L. and C.S.A. listed, F.M. approved.



Model 1823 pressure switch. U.L. and C.S.A. listed, F.M. approved.



Series 1823 pressure switch. Conduit enclosure removed to show electric switch.



Construction and dimensions. Series 1823 pressure switches.

Still our most popular pressure switches. Combine small size and low price with 2% repeatability for enough accuracy for all but the most demanding applications. Set point adjustment inside the mounting spud permits mounting switch on one side of a wall or panel with adjustment easily accessible on the opposite side.

U.L. and C.S.A. listed, F.M. approved.

***Model 1823 shown; (1823 replaces 1820, 1821 and 1822 which are similar).**

Environmental (MIL) Switch

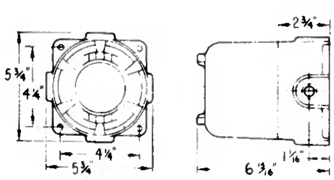
Unlisted Model 1820 can be furnished with special snap switch sealed against the environment for temperatures down to −65° F., high humidity and/or for government applications. Similar to standard Model 1823 except dead band is slightly greater. Specify Model 1820 (Range No.) "MIL" in ordering.

Weatherproof Enclosure

16 ga. steel enclosure for unusually wet or oily conditions. Withstands 200 hour salt spray test. Gasketed cover. Weight 5½ lbs. Switch must be installed at factory. Specify "WP" in addition to switch catalog number.

Explosion-Proof Housing

Cast iron base and aluminum dome cover. Approximate weight 7½ lbs. Specify "EXPL" in addition to switch catalog number.



How to Order: See price list, Bulletin S-26.

PHYSICAL DATA

Temperature limits: 32° F. (−30° for dry air, −65° with "MIL" option) to 110° F. (130° with reduced electrical rating).

Rated pressure: 10 psig one or both sides of diaphragm.

Pressure connections: ⅛" NPT.

Electrical rating: 15 amps, 120-480 volts, 60 Hz. A.C. Resistive ⅛ H.P. @ 125 volts, ¼ H.P. @ 250 volts, 60 Hz. A.C.

Wiring connections: 3 screw type, common, normally open and normally closed.

Set point adjustment: Screw type inside mounting spud.

Housing: Aluminum die casting. Steel fittings zinc plated, dichromate dipped for 200 hour salt spray test.

Diaphragm: Silicone rubber on dacron with aluminum support plate.

Calibration spring: Stainless steel.

Mounting spud: ½" pipe thread.

Weight: 1 lb., 5 oz.

SERIES 1823 SWITCHES: OPERATING RANGES AND DEAD BANDS. U.L. and C.S.A. Listed, F.M. Approved.

Model Number	Operating Range Inches, W.C.	Approximate Dead Band	
		At Min. Set Point	At Max. Set Point
1823-0	0.15 to 0.5	0.06	0.06
1823-1	0.3 to 1.0	0.08	0.08
1823-2	0.5 to 2.0	0.10	0.12
1823-5	1.5 to 5.0	0.14	0.28
1823-10	2.0 to 10	0.18	0.45
1823-20	3 to 22	0.35	0.70
1823-40	5 to 44	0.56	1 1
1823-80	9 to 85	1.3	3.0

Suggested Specification

Differential pressure switches shall be diaphragm operated with 4" diaphragm to actuate a single pole double throw snap switch. Motion of the diaphragm shall be restrained by a calibrated spring that can be adjusted to set the exact pressure differential at which the electrical switch will be actuated. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage. Switches shall be Dwyer Instruments, Inc. Catalog No. 1823-____ for the required operating ranges.

*Patent No. 3,007,017

SERIES 1823 DIFFERENTIAL PRESSURE SWITCHES

Specifications — Installation & Operating Instructions — Parts List

Dwyer

INSTALLATION AND OPERATION

INSTALLATION

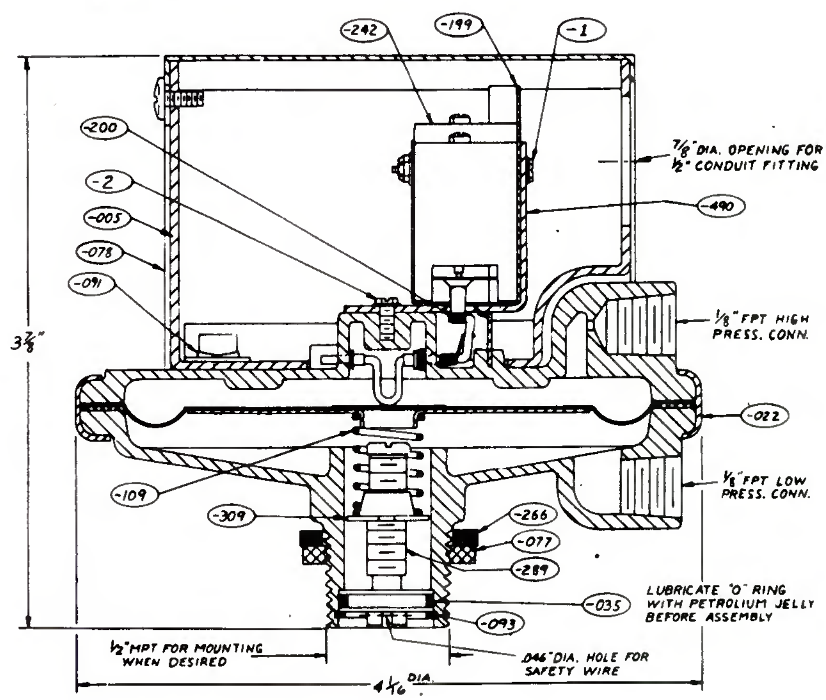
1. Select a location free from excessive vibration where oil or water will not drip upon the switch and where ambient temperature will not exceed 110°F. See special housings for unusual conditions.
2. Mount the switch with the diaphragm in a vertical plane. Must be recalibrated for each change in operating position.
3. Connect switch to source of pressure differential. Metal tubing with 1/4'' O.D. is recommended but any tubing system which will not restrict the air flow unduly is satisfactory. Note that the low pressure connection may be made to the 1/2'' stud at the back of the switch if desired. If so connected, drill 1/16'' diameter holes in the Spring Retainer flange (PN 1823-309) and the head of Adjustment Screw (PN 1823-289) to provide opening to the switch interior and plug the other low pressure connection.
4. Electrical connections for all switches are marked Common, Normally Open and Normally Closed. Be certain connections are properly made and that no mechanical load can be transferred from the wiring to the Micro Switch.

ADJUSTMENT

1. If the switch has been factory preset, check the set-point before placing in service to assure it has not shifted in transit.
2. If switch has not been preset or if it is desired to change the set point, observe the following procedure:
   a. To adjust the set point turn the slotted Adjustment Screw (PN 1823-289) clockwise to increase the set point and counterclockwise to decrease the set point.
   b. Important Note. The following is a recommended procedure for calibrating or checking calibration: Use a ''T'' assembly with three rubber tubing leads, all as short as possible and the entire assembly offering minimum flow restriction. Run one lead to the pressure switch, another to a manometer of known accuracy and appropriate range, and apply pressure through the third tube. Make final approach to the set point slowly. Note that manometer and pressure switch will have different response characteristics due to different internal volumes, lengths of tubing, oil drainage, etc. Be certain switch is checked in position it will assume in use, i.e., vertical, horizontal, etc.

PARTS LIST

Part No.	Name
1823-005	Conduit Enclosure (1)
1823-022	Switch Body Assembly — Aluminum Die Casting Diaphragm Assembly .008'' Silicone on Nylon and Aluminum Assembly Ring (1)
1823-035	''O'' Ring 1/2'' X 5/8'' (1)
1823-077	Mounting Nut — 1/2'' Electrical Nut — Steel (1)
1823-078	Conduit Cover Assembly (1)
1823-091	Conduit Enclosure Fasteners — Tinnerman Speed Nut (4)
1823-093	Retaining Ring (1)
1823-109	Calibration Spring — Stainless Steel (1)
1823-199	Insulation Shield — 1/32'' Thick Hard Fibre (1)
1823-200	Switch Button — Nylon (1)
1823-242	Micro-Switch #BZ-RW84-A2
1823-266	Mounting Washer — 1-5/32'' O.D. X .844'' I.D. — Steel (2)
1823-289	Calibration Adjustment Screw (1)
1823-309	Calibration Spring Retainer — Brass (1)
1823-490	Switch Bracket — Steel (1)
1823-1H	#6-32 X 1 Steel Screw #6L Brass Washer #6-32 Lock Nut
1823-2H	#6-32 X .5/16'' Steel Screw



Litho in U.S.A. 10-78
F. R. No. 24-440256-00

DWYER INSTRUMENTS, INC.
P. O. BOX 373, MICHIGAN CITY, INDIANA 46360, U. S. A.
Phone: AC 219, 872-9141

INVERSE TIME CURRENT RELAYS

IMPORTANT — Save for future reference.

DESCRIPTION — The Bulletin 810 is a magnetically operated current relay, with time delay, for use on AC or DC applications. It has inverse time-current characteristics which are dependent upon the viscosity of the fluid in the dashpot. However, unlike thermal relays, minimum operating current is independent of ambient temperature change or cumulative heating. The relays are supplied as standard with a normally closed (NC) contact and an automatic reset. Available options are a normally open (NO) contact, hand reset, and bifurcated contacts with a clear plastic (poly-carbonate) cover. Tripping current and time delay are adjustable.

CONTACT RATINGS —

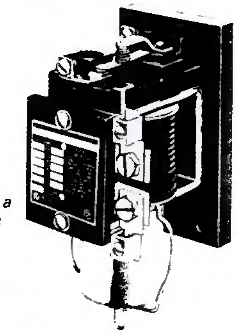
AC						DC	
Maximum Contact Rating Per Pole NEMA Rating Designation A600						Voltage Range	Ampere Rating
Max. AC Voltage 60 or 50 Hz	Amperes		Continuous Carrying Current	Volt-amperes			
	Make	Break		Make	Break		
120	60	6	10	7200	720	115-125	0.4
240	30	3	10	7200	720	230-250	0.2
480	15	1.5	10	7200	720	550-600	0.1
600	12	1.2	10	7200	720		

TIME DELAY TRIP — Current relays are used when it is desirable to take a motor off the line in a certain period of time after a predetermined load condition is reached. A typical application would be starting a large motor, where the Bulletin 810 is used to automatically open the motor starter control circuit if the motor is not up to speed in the maximum acceleration time allowed. In this and other applications of the automatic reset type relay, three wire control must be used, with a provision for interrupting the current through the relay coil immediately after the relay trips (see typical schematic diagram on page 4). On two wire control applications such as float switches, pressure switches or thermostats, a hand reset type overload relay must be used to provide this protection to the coil. The relay can carry its rated continuous current in the non-tripped position only.

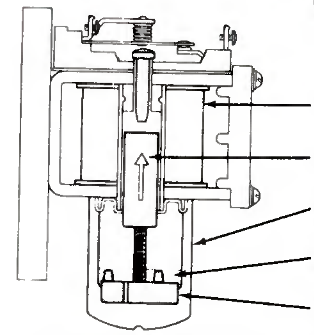
OPERATION — Current through the Bulletin 810 operating coil imparts an electromagnetic force on the movable core. The vertical position of the core in the coil is adjustable, thereby providing an adjustable trip point. When the coil current increases to the trip point, the core raises to operate the contact mechanism. Time delay is provided by a silicone fluid dashpot mounted below the core and coil assembly. An adjustable valve in the dashpot piston provides for time delay adjustment.

NORMAL CURRENT — The electromagnetic force caused by normal continuous current through the operating coil is not great enough to lift the core and piston. The relay remains inoperative.

OVERCURRENT — When the current through the operating coil increases beyond the trip point, the resultant electromagnetic force causes the core and piston to raise. Upward motion is dampened through the use of the silicone fluid dashpot. The core rises slowly until the piston reaches an increased diameter in the dashpot, where it is free, to trip the contact with a quick action. Time and current required to complete this cycle are inversely related as shown by the time-current characteristics curves on page 2.



Bulletin 810 relay with a maximum continuous current rating of 60 amperes.



Cross sectional view. Moving parts are shaded.

RESET — Standard models of the Bulletin 810 are automatically reset as soon as the current through the coil is interrupted or decreased to approximately 20% of the tripping current. The core is designed to drop quickly, returning the contacts to their normal position. A check valve allows the piston to bypass the fluid in its return to the bottom of the dashpot. The action of hand reset models differs only in that the contacts do not reset until a lever on the contact block is operated. There is no waiting period as with thermal relays.

EFFECTS OF AMBIENT TEMPERATURE — The minimum operating current (100% on the time-current characteristics graph) is independent of ambient temperature at the relay. However, the operating time at overcurrent varies directly to the viscosity of the silicone fluid. Since the viscosity varies inversely with ambient temperature, the operating time is also inversely affected. The time temperature table shows the correction factors to be applied to the operating times for various temperatures.

TIME TEMPERATURE RELATIONSHIP (+40° C Reference) —

Ambient Temperature (°C)	0°	+10°	+20°	+30°	+40°
Operating Time Correction Factor	2.25	1.80	1.45	1.20	1.0

Publication 810-5.0 — November, 1977
Supersedes Publication 810-5.0 Dated October, 1976

OPERATING CURRENT ADJUSTMENT — (Not necessary if factory set to user's specified value). The minimum operating current (100% on the time-current characteristics graph) is adjusted by changing the vertical position of the core within the operating coil. Calibration lines on the core correspond to current values in the table below and stamped on the nameplate. After the core and dashpot assembly is removed, the core is turned up or down on the piston's threaded stem till the line corresponding to the desired operating current is in line with the **top edge of the dashpot**. Currents other than those indicated by the lines are possible by interpolation.

NOTE: If electrical tests are made of current calibrations they should be done **without** fluid in the dashpot (clean and dry).

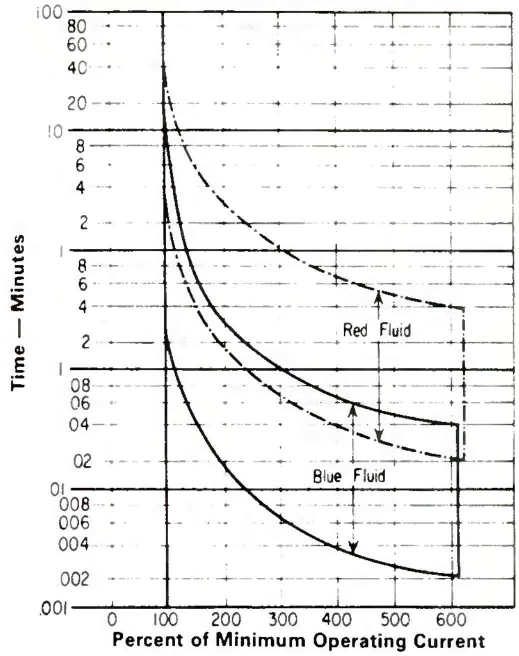
ADDING DASHPOT FLUID — (See note above) The dashpot fluid is shipped separately. To add fluid, remove the core and dashpot assembly by unfastening the spring clamp. Remove the dashpot cover by pulling the core straight out of the dashpot. Remove and discard red plastic shipping spacer if present. Add the silicone fluid with the dashpot cover removed, with the piston and core in place. Fill the dashpot to the top of the three round projections on the piston. See illustration below. The fluid must be free of dirt or grit, and the dashpot and piston must be **absolutely clean. Check fluid level periodically.**

OPERATING TIME ADJUSTMENT — Unless ordered with a specified time delay setting, the relays are set for minimum time delay when shipped. To increase the time delay, remove the piston from the dashpot and decrease the opening of the adjustment valve by rotating its cover counterclockwise. See illustration below.

CAUTION: Do not attempt to change the position of the check valve cover, which holds the steel balls of the check valve in place.

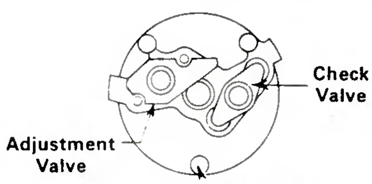
The range of operating times possible with the Bulletin 810 is shown by the time-current characteristics curves to the right. The area labeled "blue fluid" represents the range of curves possible using the low viscosity blue fluid supplied as standard with the relay.

TIME-CURRENT CHARACTERISTICS AT + 40°C

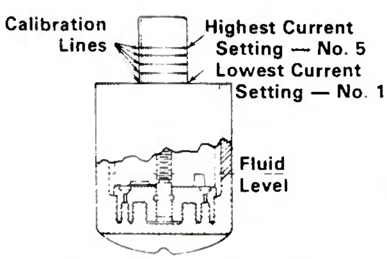


The overlapping area labeled "red fluid" represents the range of curves possible with a higher viscosity red fluid, supplied when requested. Each area is bounded by curves that represent the operating times with the valve fully opened and fully closed. Intermediate settings must be verified by electrical tests.

COIL CURRENT — The maximum continuous current rating of the coil appears on the relay nameplate. The current at which the relay is set to trip should not exceed this value except when an additional device protects the coil against sustained overcurrent. To avoid relay damage, **current** through the relay coil **must be interrupted** after the relay trips. Relay can carry rated continuous current in the non-tripped position only.



Top View of Piston

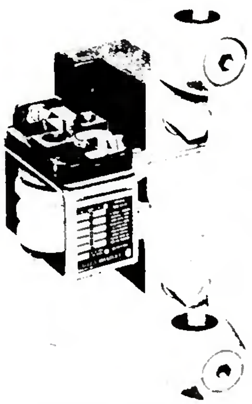


Core and Dashpot Assembly

1 Catalog numbers are for single relays in the open type construction, with NC contacts and an automatic reset. The calibration table also applies to catalog numbers beginning with the letter B, C, K, or L and ending with the letter B, C, or D.

Max. Continuous Coil Current Amps.	Catalog Number 1	AC Calibrations					DC Calibrations					Coils 600V Max. 60 Hz Max.
		1	2	3	4	5	1	2	3	4	5	Part No.
2	810-A01A	1.1	1.5	2.0	2.6	3.1	0.95	1.4	1.9	2.3	2.8	X-67400
3	A02A	1.6	2.3	3.0	3.8	4.5	1.4	2.1	2.9	3.5	4.3	X-67404
4	A03A	2.1	3.0	4.0	5.1	6.1	1.9	2.9	3.8	4.7	5.7	X-67407
6	A04A	3.2	4.5	6.0	7.6	9.1	2.8	4.3	5.7	7.0	8.5	X-67415
9	A05A	4.8	6.8	9.0	11.4	13.6	4.2	6.4	8.5	10.5	12.8	X-67420
12	A06A	6.3	9.0	12.0	15.2	18.1	5.7	8.5	11.4	14.0	17.0	X-67425
16	A07A	8.5	12.0	16.0	20.5	24.0	7.6	11.3	15.1	18.6	22.7	X-67429
20	A08A	10.5	15.0	20.0	25.5	30.0	9.4	14.1	18.9	23.2	28.3	X-67433
28	A09A	15	21	28	36	43	13	20	27	33	40	X-67439
40	A10A	21	30	40	51	61	19	29	38	47	57	X-67444
48	A11A	25	36	48	61	72	23	34	46	56	68	X-67454
56	A12A	30	42	56	72	85	27	40	54	66	80	X-67457
60	A13A	38	54	72	91	108	34	51	68	84	102	X-67461
72	810-A14A	38	54	72	91	108	34	51	68	84	102	X-86996
87	A15A	46	65	87	110	130	41	61	82	101	123	X-86999
100	A16A	53	75	100	126	150	47	71	94	116	141	X-87001
108	A17A	57	81	108	138	163	51	77	103	126	153	X-87002
120	A18A	68	97	130	165	195	61	92	123	151	184	X-67480
120	A19A	76	108	145	183	217	68	102	137	168	205	X-67479
130	810-A20A	68	97	130	165	195	61	92	123	151	184	X-88199
144	A21A	76	108	144	183	217	68	102	136	167	204	X-88198
162	A22A	85	121	162	205	244	76	115	153	188	229	X-88197
185	A23A	98	139	185	235	279	87	131	175	215	262	X-88196
210	A24A	114	162	216	274	325	102	153	204	250	305	X-88195
216	810-A25A	114	162	216	274	325	102	153	204	250	305	X-90713
259	A26A	136	194	259	328	390	122	184	245	300	367	X-90712
320	A27A	171	242	328	411	488	152	229	306	376	458	X-90711
320	A28A	227	323	432	547	650	203	305	405	502	612	X-90710

RENEWAL PARTS



Pedestal Mounted Relay

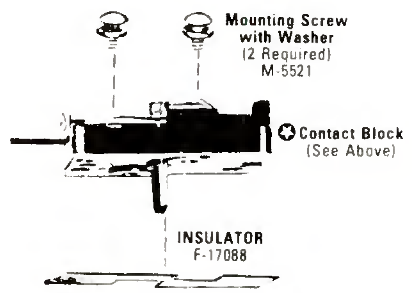
Steel Panel Mounted Relay

Slate Panel Mounted Relay

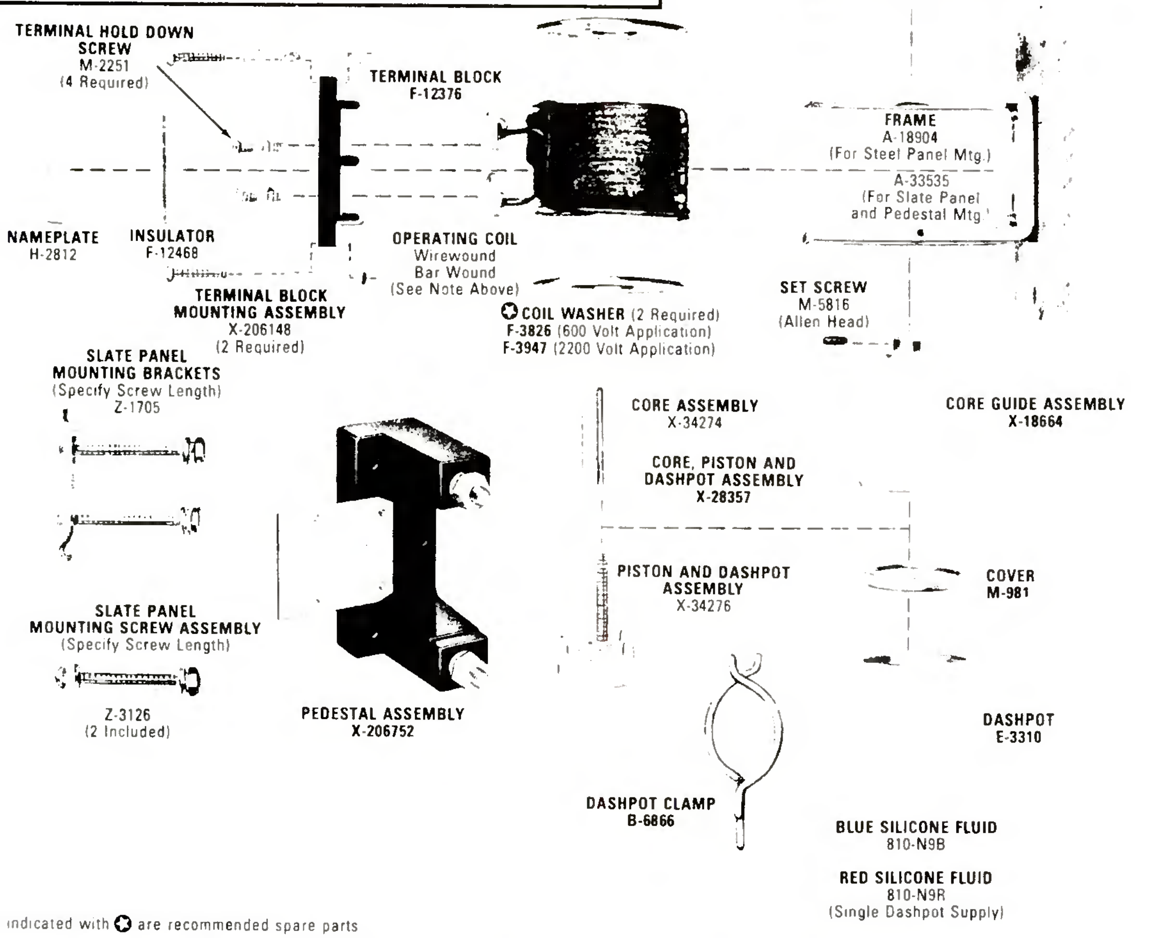
✪ **CONTACT BLOCK**
Z-11011 (NO Hand Reset)
Z-11012 (NC Hand Reset)
Z-11013 (NO Automatic Reset)
Z-11014 (NC Automatic Reset)
Z-15227 (NC Automatic Reset with Blowout Magnet)

Z-33833 (NO Hand Reset Bifurcated Contacts)
Z-33831 (NC Hand Reset Bifurcated Contacts)
Z-33834 (NO Automatic Reset Bifurcated Contacts)
Z-33832 (NC Automatic Reset Bifurcated Contacts)

NO — Normally Open
NC — Normally Closed



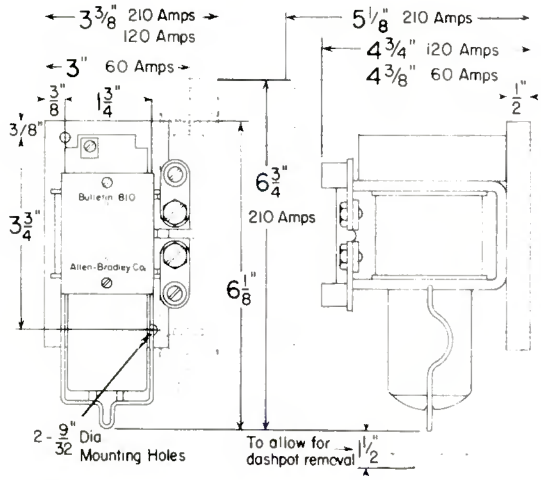
TO REPLACE THE COIL — Remove the dashpot assembly, contact block, insulator, and coil terminations. On steel panel mounted relays also remove nameplate and its insulator, and the terminal block. Remove set screw holding core guide assembly in side of frame and push core guide assembly down and out. Remove coil washers and coil. Reassemble by reversing above procedure. **Tighten** all fasteners **securely**.



Parts indicated with ✪ are recommended spare parts

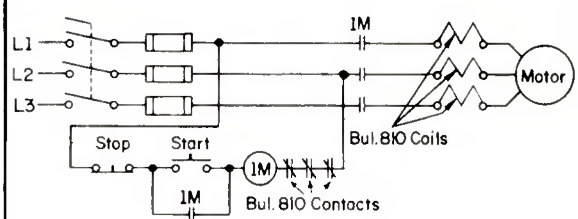
ORDERING INFORMATION — Your order cannot be entered unless the following information is given: Part number, description of part, catalog number and series letter of the relay. This instruction sheet applies also to the above relays when used on control apparatus listed under other Bulletin numbers.

APPROXIMATE DIMENSIONS

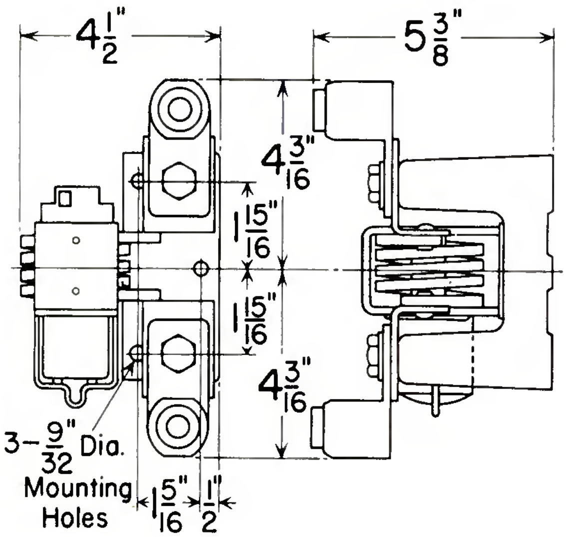


OPEN TYPE
Maximum Current thru 60, 120, and 210 Amp.

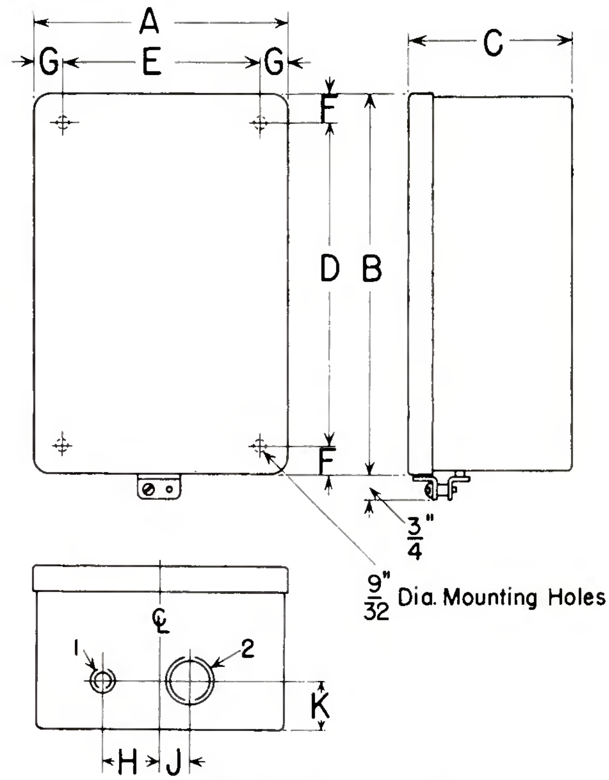
TYPICAL SCHEMATIC DIAGRAM
(See Applicable Codes and Laws)



Three Bulletin 810 relays used for overload protection.



OPEN TYPE
Maximum Current thru 320 Amp.



NEMA Type 1 Enclosure

Number of Relays	Maximum Continuous Current Amperes	NEMA **Type 1 Enclosure** — Dimensions in Inches										Conduit Sizes in Inches	
		A Wide	B High	C Deep	D	E	F	G	H	J	K	1 Top & Bottom	2 Top & Bottom
Single Relay	60	6⅜	11⅜	6⅛	9¼	4¼	1 1/16	1 1/16	1¼	⅞	2 1/16	½ & ¾	1 & 1¼
	120	6⅜	11⅜	6⅛	9¼	4¼	1 1/16	1 1/16	1¼	⅞	2 1/16	½ & ¾	1 & 1¼
	210	7⅜	16⅜	7¾	14¼	5¼	1 1/16	1 1/16	1¾	⅞	2	½ & ¾	1½ & 2
	320	9⅜	21⅜	7¾	19¼	7¼	1 1/16	1 1/16	1⅞	1⅛	2⅝	½ & ¾	2 & 2½
Two Relay Panel	60	9⅞	11⅜	6⅛	9¼	7¾	1 1/16	1 1/16	2	1¼	2 1/16	½ & ¾	1¼ & 1½
	120	9⅞	11⅜	6⅛	9¼	7¾	1 1/16	1 1/16	2	1¼	2 1/16	½ & ¾	1¼ & 1½
	210	10⅜	16⅜	7¾	14¼	8¼	1 1/16	1 1/16	2	1¼	2 5/16	½ & ¾	2 & 2½
	320	12⅞	21⅜	7¾	19¼	10¾	1 1/16	1 1/16	3	1¾	2 9/16	½ & ¾	2½ & 3

TRANSISTORS

2N3904

NPN Silicon
Switching Transistor

60V @ 0.2 amperes
625 mW

2N3906

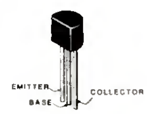
PNP Silicon
Switching Transistor

60V @ 0.2 amperes
625 mW

2N4401

NPN Silicon
Switching Transistor

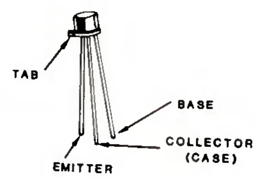
40V @ 0.6 amperes
350 mW



2N4239

NPN Silicon
Driver Transistor

80V @ 3 amperes
6 watts



2N6282

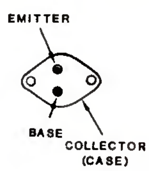
NPN Darlington
Power Transistor

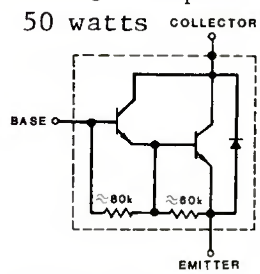
60V @ 20 amperes
160 watts

2N6294

NPN Darlington
Power Transistor

60V @ 4 amperes
50 watts

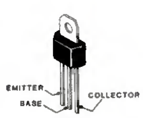


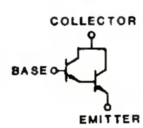


MPS U45

NPN Darlington
Driver Transistor

40V @ 2 amperes
10 watts

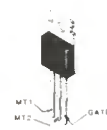




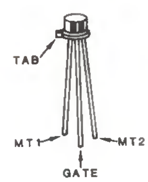
WARNING: Disconnect primary power prior to servicing.

THYRISTORS

2N5060	Silicon Controlled Rectifier	30V @ 0.8 amperes
T1C206A	Triac	100V @ 3 amperes

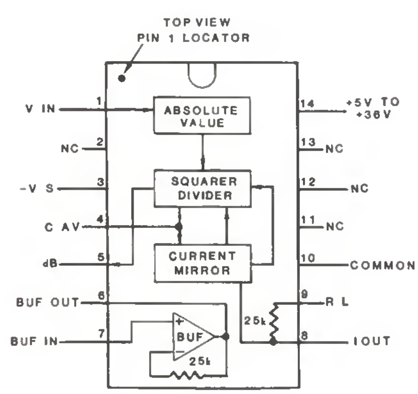


2N5756	Triac	400V @ 2 amperes



INTEGRATED CIPCUITS

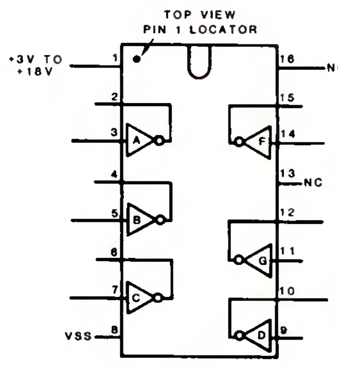
AD 536 J   RMS-to-DC converter



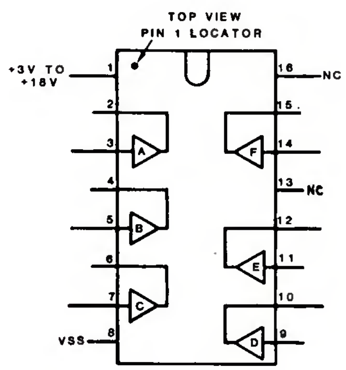
WARNING: Disconnect primary power prior to servicing.

INTEGRATED CIRCUITS (Continued)

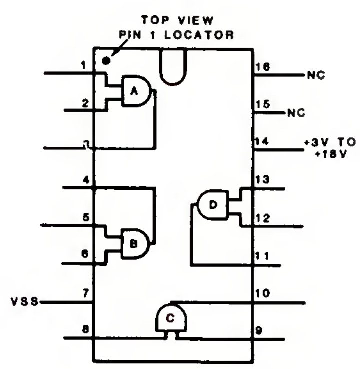
CD 4049 AE Inverting Hex Buffer



CD 4050 AE Non-Inverting Hex Buffer



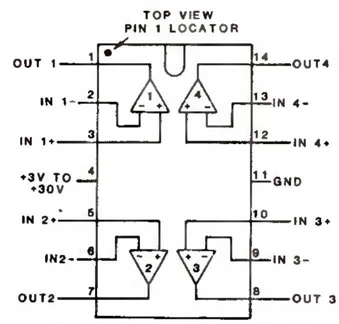
CD 4081 AE Quad 2-Input AND Gate



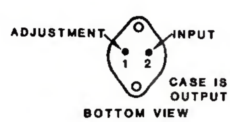
WARNING: Disconnect primary power prior to servicing.

INTEGRATED CIRCUITS (Continued)

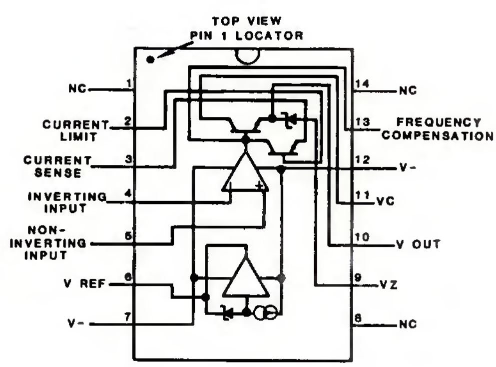
LM 324 N — Quad Operational Amplifier



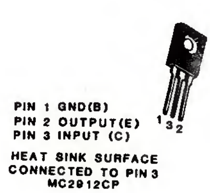
LM 317 K — Adjustable Positive Voltage Regulator — +1.2V to 37V @ 1.5 amperes



LM 723 CD — Adjustable Positive Voltage Regulator — +2V to +37V @ 0.150 amperes

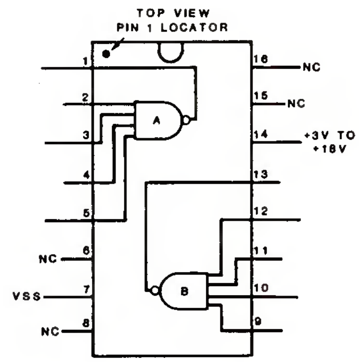


MC 7912 CP — Fixed Negative Voltage Regulator — -12V @ 1.5 amperes

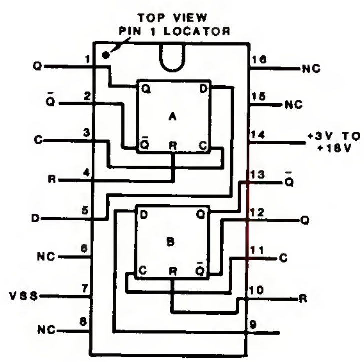


WARNING: Disconnect primary power prior to servicing.

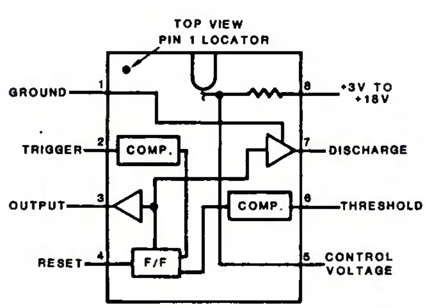
MC 14012 BCL — Dual 4-Input NAND Gate



MC 14013 BCL — Dual Type-D Flip-Flop



NE 555 N — Timer



WARNING: Disconnect primary power prior to servicing.

ENGINEERING
REPORT

SUSCEPTIBILITY OF THE OPEN-DELTA CONNECTION TO THIRD HARMONIC AND TRANSIENT DISTURBANCES

HARRIS
COMMUNICATIONS AND
INFORMATION HANDLING

WARNING: Disconnect primary power prior to servicing.

SUSCEPTIBILITY OF THE OPEN-DELTA CONNECTION TO THIRD HARMONIC AND TRANSIENT DISTURBANCES.

In certain instances, three phase power is distributed using a transformer connection commonly known as the "Open-Delta" or "V-V" connection. This connection, using two identical transformers, is susceptible to third harmonic distortion and line transients which are normally nullified in a standard wye-delta transformer connection.

To illustrate this inherent difficulty, the problem is approached both theoretically and experimentally.

I. THEORETICAL APPROACH:

Figure 1 illustrates the standard wye-delta connection, utilizing three phase, four wire power, identical transformers, and balanced loads. In the figure, I_1, I_2, and I_3 are the phase currents to the load. I_m is a circulating magnetizing current present in the transformer secondaries.

In the closed delta connection, I_m, the magnetizing current, circulates around the delta. Exhibiting large third harmonic components, this current is responsible for producing sinusoidal line voltages. Note that phase voltages, those across each secondary, are sinusoidal, due to the production of a third harmonic voltage. It should be noted that the third harmonic current must have a path to flow in order that sinusoidal voltages may be produced across the transformer secondaries.

Consider the Open-Delta connection, illustrated in figure 2. In this diagram, I_m is not shown. In the open-delta configuration, the third harmonic component, I_m, in addition to flowing in the transformer secondaries, also flows into the various three phase loads. Thus, the voltages across the various three phase loads have the normal sinusoidal component plus a third harmonic component induced by the triplen harmonic current now flowing through the load.

To further clarify the issue, refer to the normal wye-delta connection. I_m contains the third harmonic components, while I_1, I_2, and I_3, are the various line currents associated with the resultant sinusoidal phase voltages. In the open delta connection, I_1,I_2, and I_3, are again the line currents. However, each contains a third harmonic component. The third harmonic current, I_m above, must still be present in the secondary coils. However, lacking a circulating path, this current must now pass through the various phase loads. As this occurs, each sinusoidal line voltage becomes added to a third harmonic, resulting in the waveshape of figure 5 or 6, with a peak value of E_t greater than E_m, the corresponding sinusoidal peak value. Normal three phase waveshapes are shown in figure 4, A,B,&C.

Referring back to figure 2, it may be seen that the third harmonic waveshape of figure 5 or 6 may in essence be impressed across the two loads which bridge only one coil (Z_2 and Z_3). However, Z_1, the load across the entire secondary array, is under the influence of two phase voltages. The graphical result is shown in figure 7. Note that the form of the resultant is periodic, symmetrical, but non-sinusoidal.

Since the three phase load is in this case, a delta connected set of transformer primaries, feeding wye connected secondaries, the problem of rectification at the final output becomes acute. The delta connected primaries are being supplied with what is effectively unbalanced, non-sinusoidal voltage, with a peak value greater than supplied line voltage. Through normal transformer action then, the final voltages across the wye connected power rectifiers are of sufficient value to exceed the rectifier ratings and cause component failure.

II. EXPERIMENTAL APPROACH:

If the above theoretical discussion is valid, a simple experimental set-up will verify the discussion. This apparatus is shown in figure 3. Provision has been made in the test arrangement to switch immediately from standard wye-delta to the open-delta connection.

Under test conditions, figure 4,A,B,&C illustrates actual phase voltages provided by the standard wye-delta connection.

Figures 8, 9, and 10 show the actual phase voltages produced by the open-delta connection.

If figure 8 is compared to figure 5, figure 9 to figure 6, and figure 10 to figure 7, basic similarities are quickly seen. Accounting for scale differences and imbalance of phase voltages, a recognized fault of the open-delta connection, the three actual output waveforms conform quite closely to the theoretical graphical results. In addition, line and switching transients may be noted in the experimental outputs of the open-delta system. These sharp transients, as much as 300% of the peak phase voltage, are viewed across the phase loads, and may be attributed to the common connection of the neutral from primary to secondary windings.

Problems involving over-voltage at the phase loads cannot be attributed to large third harmonic peaks on the distorted waveforms. By experimentation, the peak voltages of the unbalanced phase voltages of the open-delta system were 52.6%, 112%, and 68.5% of the peak voltages exhibited by the closed-delta system. Problems with the loads arise as the result of high line transients, and normal transformer action as a non-sinusoidal waveform containing a large third harmonic component is applied to the load transformer primaries.

It must be noted that experimental results were not always consistent. At times, as power was applied to the open-delta connection, nearly sinusoidal, slightly unbalanced phase voltages were produced. During such operation, except for susceptibility to line transients, the open-delta system appears to function satisfactorily.

The explanation of this phenomena involves the relative phasing of the third harmonic components in the transformer secondaries. Under certain phase relationships, if power is applied during certain segments of the line cycle, the third harmonics produced will add to the phase voltages to produce a nearly sinusoidal waveshape at the phase loads. Another very important consideration concerning the open-delta connection deals with the point in line phase in which the power has been removed from the system. Residual flux and magnetism in the transformer cores may play an important part in the performance of the system when power is again applied. Thus, at times, the open-delta system may appear to function nearly as well as the wye-delta connection, when residual flux and applied phase relationships combine to produce a sinusoidal output. These considerations then explain the fact that phase loads may not fail consistently, but rather in a random fashion, depending upon the line transients, residual flux, and line phase relationships at the instant of application of power to the load.

Non-sinusoidal phase voltages, rich in third harmonic content, susceptibility to line and switching transients, and imbalance of phase voltages are problems inherent with the open-delta connection. Only in an emergency should this arrangement be used for power distribution, and even then not to supply loads which are inherently susceptible to damage from transients and/or irregular supply voltages.

III. VARIATION OF LOAD:

The preceding discussion has been in reference to an extremely lightly loaded open delta system. In that instability was noticed in the system and experimental data, it was decided to test the system under varying load conditions.

The system loading was varied from 50% of transformer ratings to a very small percentage, keeping the phase loads balanced and resistive.

The results of this system test are shown in figures 11 and 12.

Figure 11 shows phase voltage magnitude, while figure 12 illustrates phase angle, versus transformer loading.

It was shown that, as the phase loading was increased (resistance decreased), results were constant down to 100 ohms per phase, or about 1% of transformer rating. Down to this point, the third harmonic behavior of the system, as described earlier, could be induced by applying a heavy load to any one phase. It also could occur as power was applied to the system.

Down to this point, under non 3rd harmonic behavior, phase voltages were not critically unbalanced, and phase angle relationships were correct.

The graphical results in figures 11 and 12 show the open delta behavior between .1% and 50% of transformer ratings. Notice that, as loading is increased, the phase angle relationship changes from 0°-120°-240° to 0°-0°-180°, and the phase magnitude relationship changes from relatively balanced three phase to highly unbalanced three phase, to two phase.

Above .3% of transformer ratings, 3rd harmonic operation could not be induced, and the graphical results included were the only operation obtained using the experimental apparatus.

IV. A. SUMMARY:

On the basis of the above, it is reasoned that one of four conditions is present causing consumer problems:

A. Transformers are very lightly loaded, causing the 3rd harmonic currents present in the open-delta connection load to severely distort and unbalance the load phase voltages at times, causing subsequent component failure.

B. Transformers are moderately loaded, causing the three phase power to appear at phase angles quite different from the expected 0°-120°-240° relationship. This phase variation causes severe imbalance between individual phases and ground, may unbalance the load, and may cause component failure.

C. Transformers are heavily loaded, performing close to maximum allowable for the open delta configuration. This condition causes the third normal phase to be cancelled by the other two phases which appear at 0° and 180°. Thus, with 2 phase, 0°-180° power being supplied to the load, component failure results.

D. Transient susceptibility of the open delta connection allows line transients to be fed to the loads. Such transients as those caused by rapid application of load, motor starting, etc., may be as high as 300% of line voltage, and may cause component failure.

IV. B. EFFECT OF OPEN DELTA 3 PHASE

POWER ON BROADCAST TRANSMITTERS

With reference to "Susceptibility of the Open-Delta Connection to Third Harmonic and Transient Disturbances by D. R. Dening, it is seen that there are several different effects on a transmitter that can be produced by an "open delta" three phase system.

Obviously, in designing and developing transmitters a straight forward 3 phase supply is assumed because there is no way that we as transmitter manufacturers could predict the behaviour of any given "open delta system" in advance.

Referring to the above mentioned report, an "open delta" system can develop a considerable imbalance between phases either in voltage or in phase, or both. When this occurs, there is produced in the output of all 3 phase d.c. power supplies, a very strong 120 hertz ripple frequency.

Normal three phase supplies have a 360 Hz ripple frequency and their corresponding filtering is designed accordingly. To design a high voltage power supply that would also knock out a 120 hertz ripple would add considerably to the cost of the transmitter and is economically impractical.

The "open delta" supply can under other conditions of load produce very high 3rd harmonic energy. Such harmonic content produces severe transients which besides adding noise to the power supply output, severely strain rectifiers, capacitors chokes and transformers and has many times resulted in premature component failures. A considerable amount of transient suppression is built into most transmitters, but transients of sufficient magnitude far in excess of practical protection have been observed in transmitters connected to an "open delta" system.

Portions of the electrical power for control circuits, filaments, etc. of all transmitters are supplied single phase from one of the three phases supplying the high voltage within the transmitter.

This single phase load is distributed between the three phases as well as possible to help prevent unbalance.

The above report shows it is possible for one phase to completely disappear from the system in an "open delta" connection under certain load conditions. Naturally, if this occurs to the phase supplying some of the filament power or the control circuits, this source of power is completely lost to the transmitter and while transmitters are generally protected against this condition, it is still impossible to operate the unit until the 3rd phase returns.

V. FIGURES

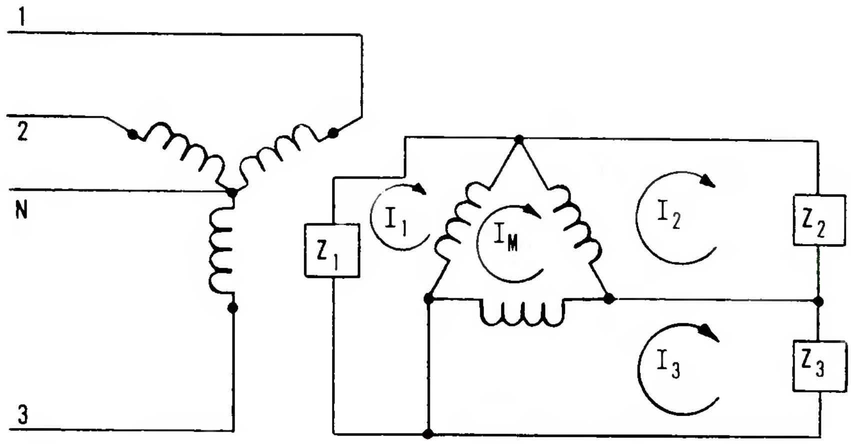


Figure 1: Standard Wye-Delta Transformer Connection

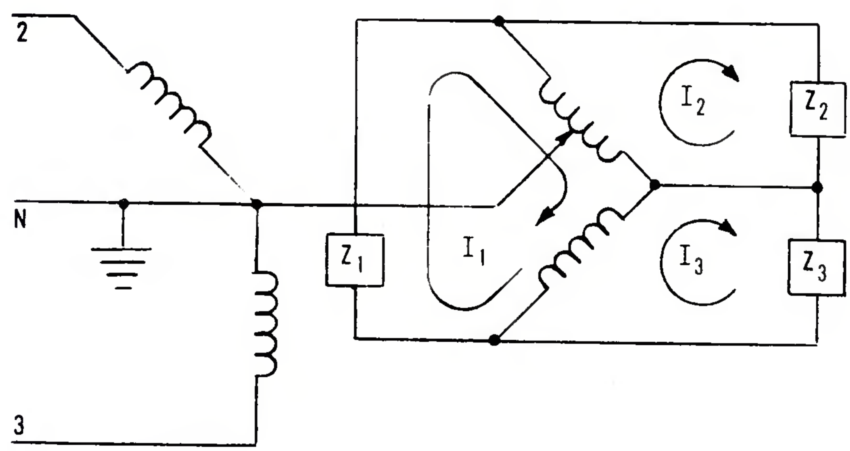


Figure 2: Open-Delta or "V-V" Connection

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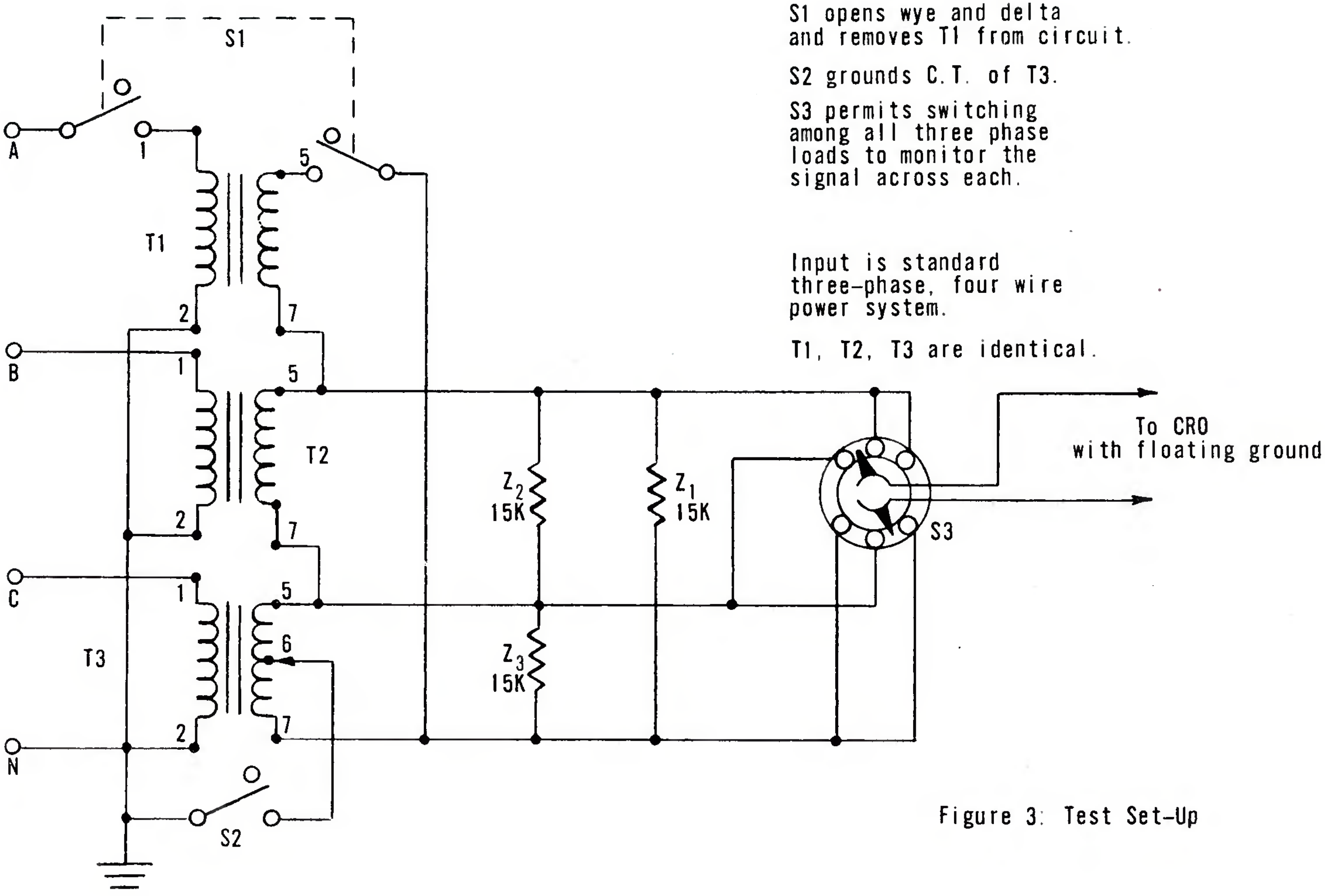

S1 opens wye and delta and removes T1 from circuit.

S2 grounds C.T. of T3.

S3 permits switching among all three phase loads to monitor the signal across each.

Input is standard three-phase, four wire power system.

T1, T2, T3 are identical.

Figure 3: Test Set-Up

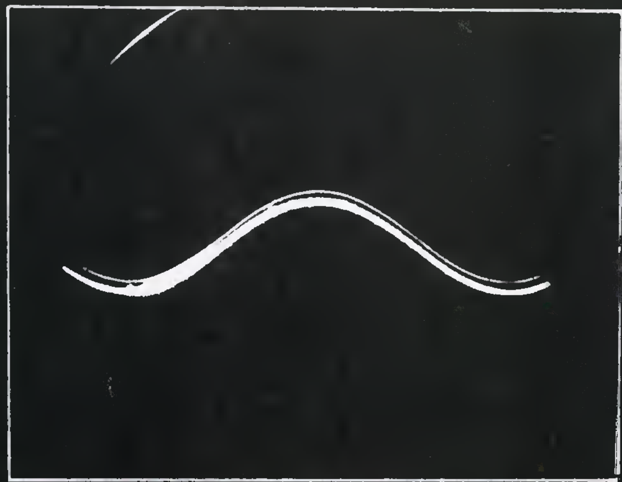

Figure 4A

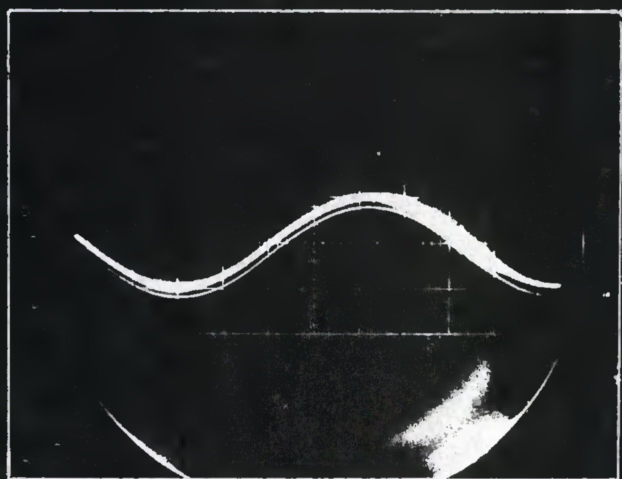

Figure 4B

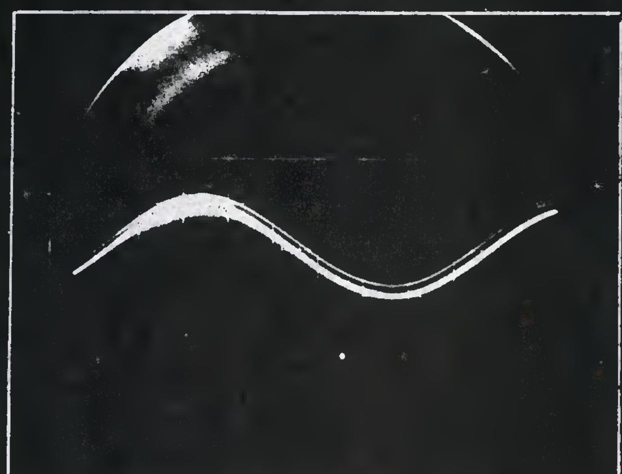

Figure 4C

Figures 4A, 4B, and 4C are photographs of the resultant CRO traces of the various three phase voltages across the loads when the standard wye-delta connection is tested.

Inputs to the system are virtually identical in shape

Note the undistorted three phase, balanced waveshapes, characteristic of the normal wye-delta connection.

With this transformer connection, the output voltages are not particularly sensitive to input transients or switching pulses.

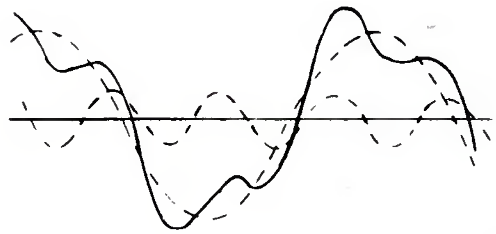

Figure 5: The fundamental sinusoidal waveform (dotted), accompanied by a third harmonic waveform (dotted). Graphical addition gives theoretical resultant waveshape.

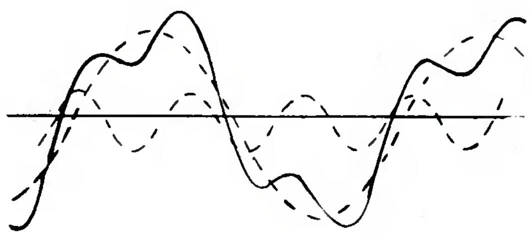

Figure 6: Similar to figure 5. Here, the third harmonic component is in a different phase relationship with the fundamental. Graphical theoretical resultant waveshape is again shown as a heavy line.

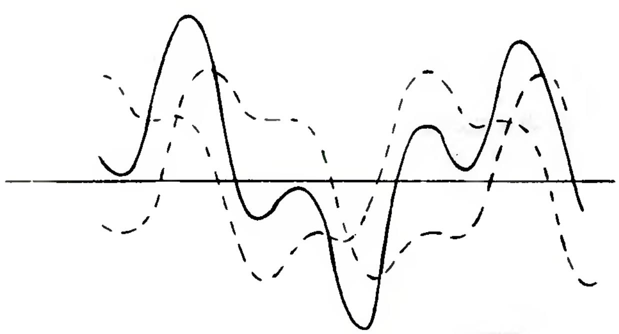

Figure 7: Two third-harmonic distorted waveshapes, as above, are graphically added, 120° out of phase, to illustrate a theoretical resultant, shown as a heavy line.

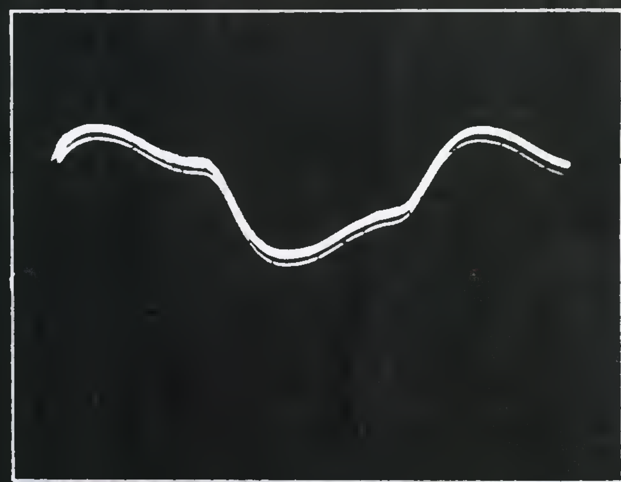

Figure 8: Output across load Z2 with open-delta connection under test.

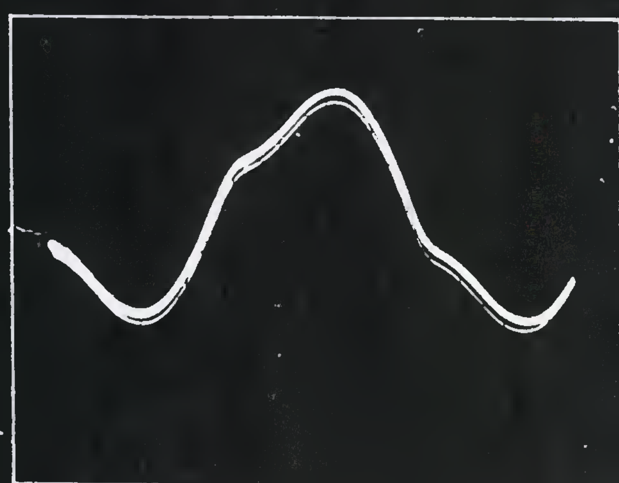

Figure 9: Output across load Z3 with open-delta connection under test.

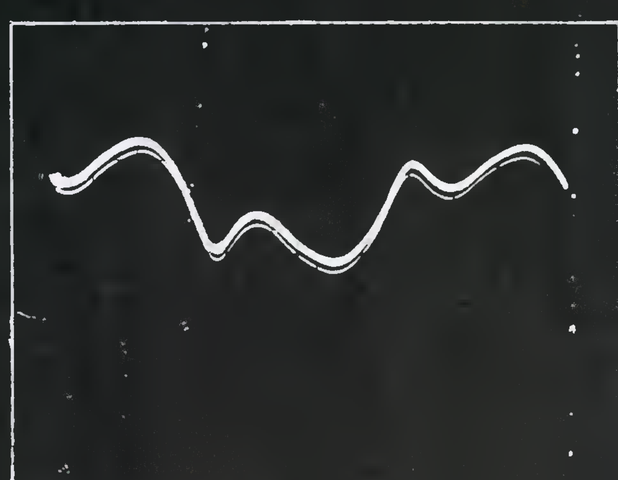

Figure 10: Output across load Z1 with open-delta connection under test.

Figures 8,9, & 10 are reproductions of CRO trace photographs under test conditions.

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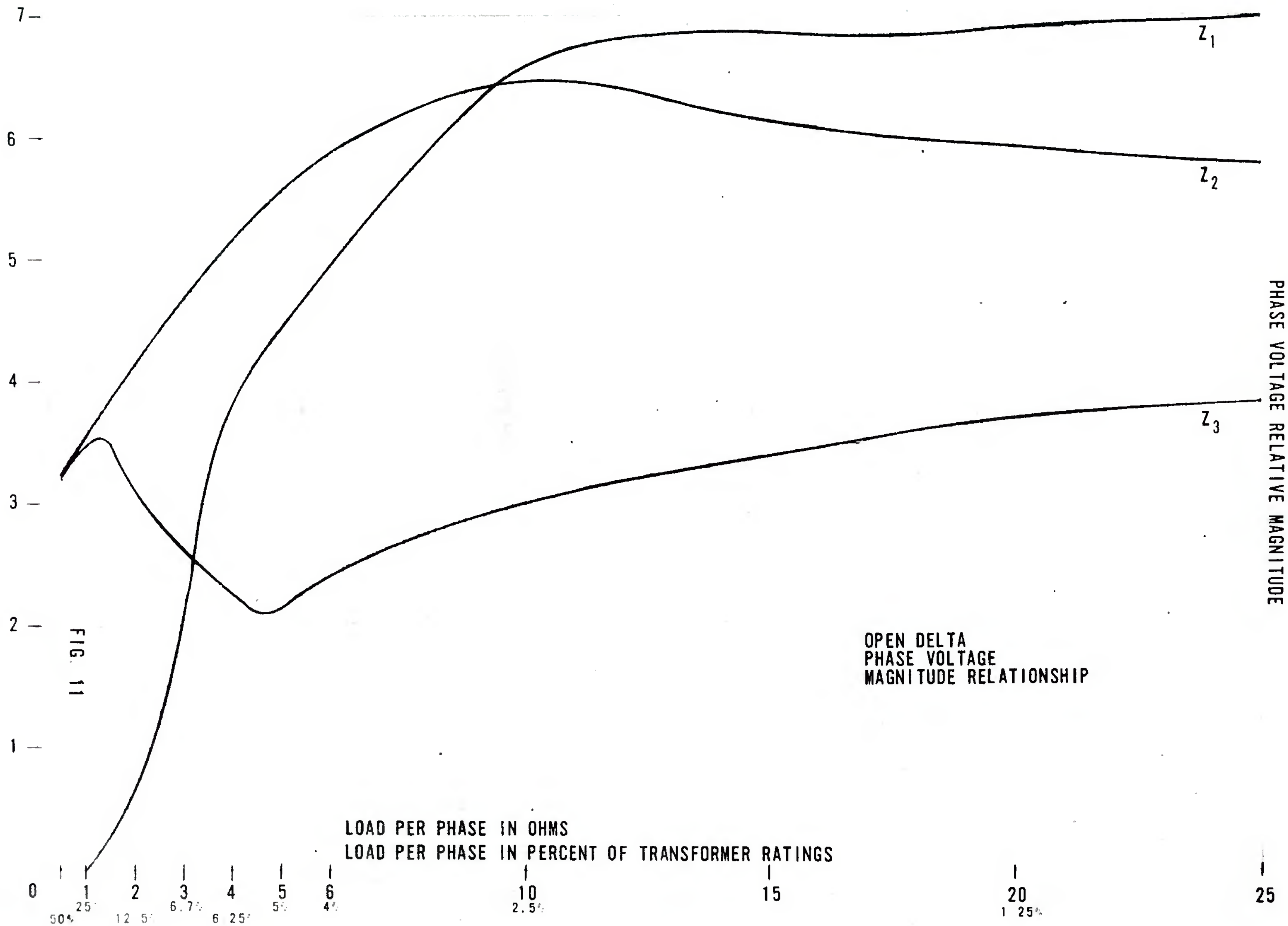

FIG. 11

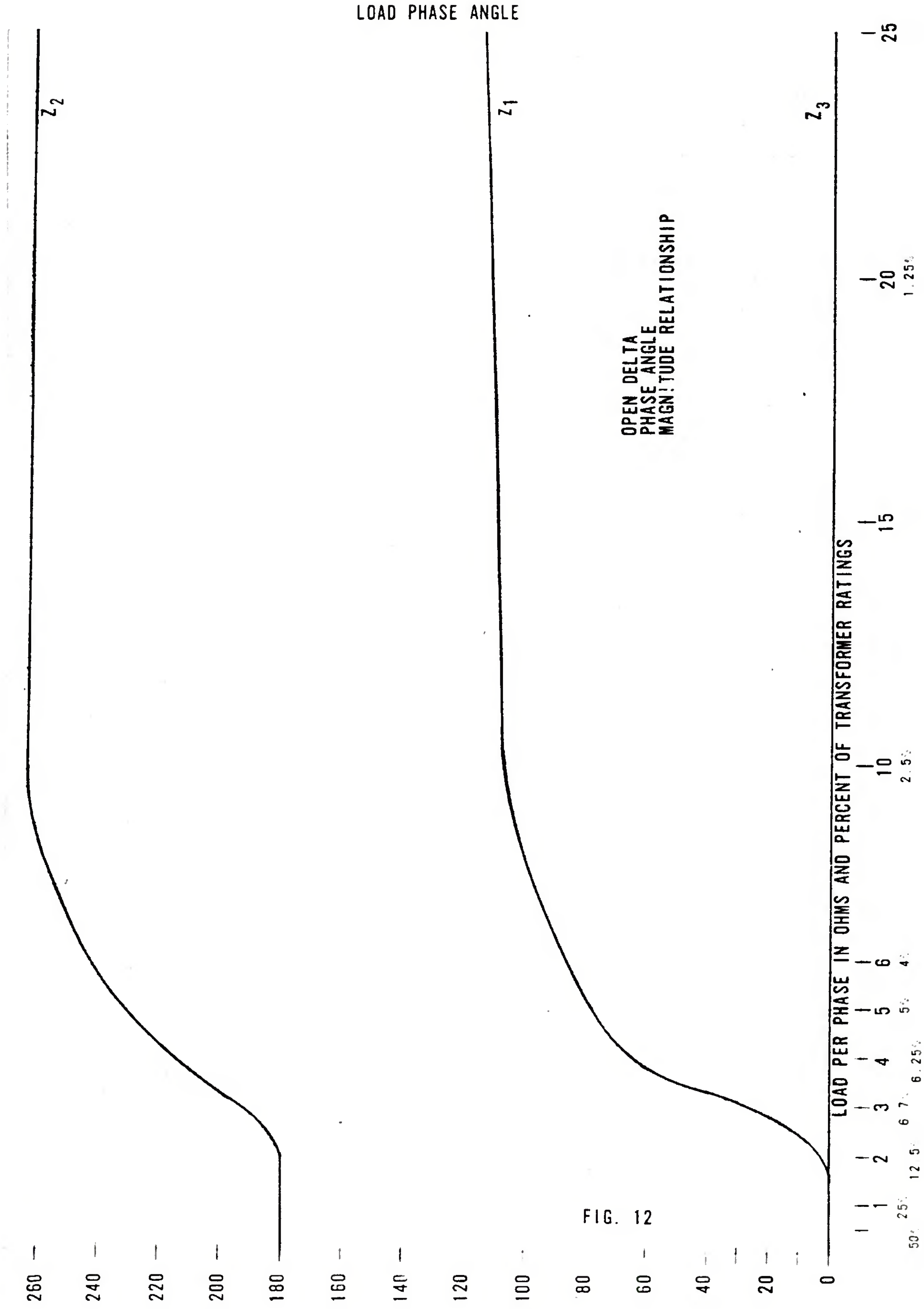

FIG. 12

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QUARTER AND HALF WAVELENGTH TUBE TYPE CAVITIES FOR FM AND TV USE

BY: CLARENCE "DOC" DAUGHERTY

F.M. TUBETYPE CAVITY RF POWER AMPLIFIER CONSIDERATIONS

BACKGROUND:

When amplifiers were first built they were able to handle audio frequencies only. As the operating frequency increased the interelectrode capacity of the vacuum tube and the distributed capacity of the circuit (lumped together they can be referred to as stray capacity, C_s) tends to shunt the signal to ground. (See Figure 1). This limits the high frequency response of the amplifier.

One method used to overcome the shunting effects of stray capacity (C_s) is to lower the resistive load impedance of the amplifier.

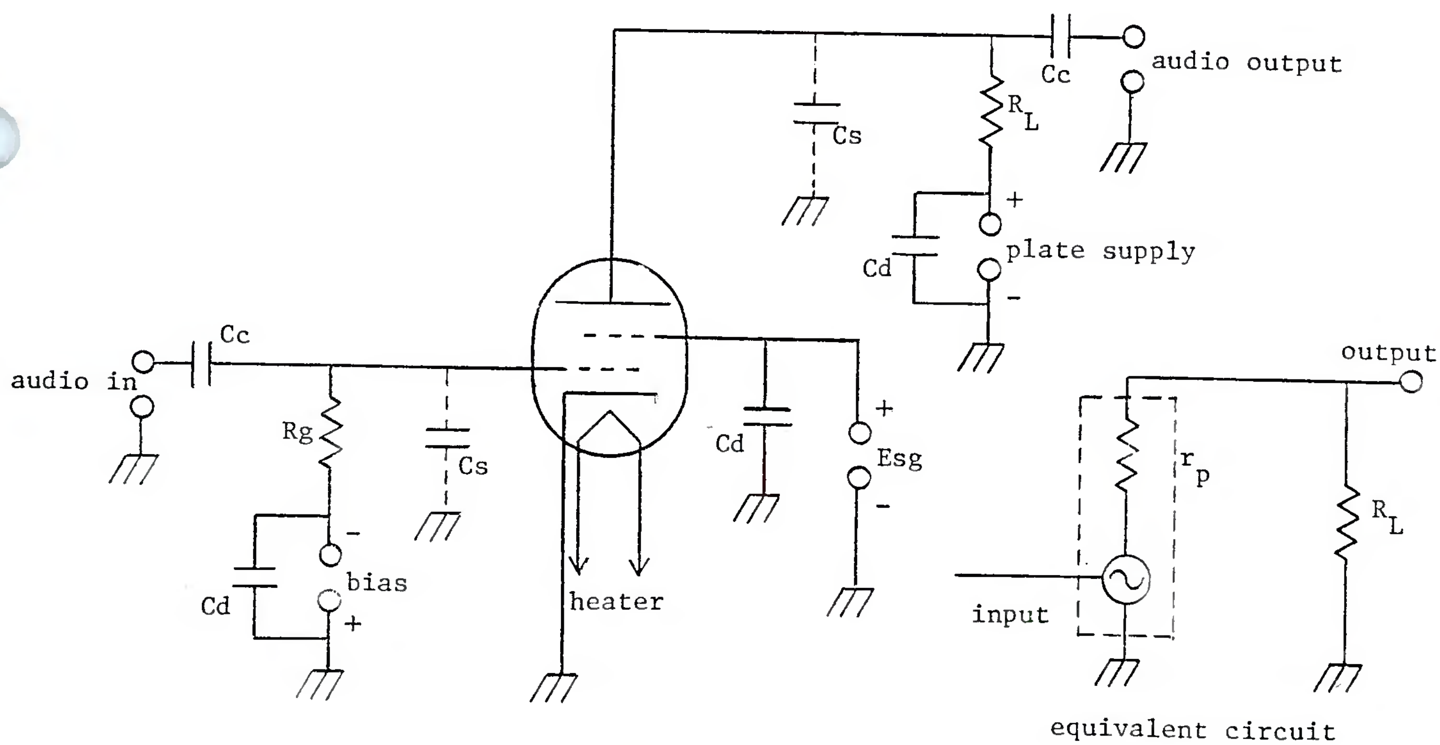


FIGURE 1 - A tube type amplifier and the equivalent circuit

High frequency rolloff is determined by the formula:

$$f_{max} = \frac{1}{2\pi R C_s}$$

Where: f_{max} = Maximum frequency output. At this point the voltage gain is 0.7 of maximum and the power gain is half of maximum (The -3db point).

R = The plate load resistance or the grid load resistance

C_s = The plate circuit stray capacity if R_L is used, or the input circuit stray capacity if R_g is used.

The voltage gain of the amplifier is determined by the formula:

$$A_v = \frac{-R_L}{R_L + r_p}$$

Where: A_v = Amplifier voltage gain

r_p = The internal plate resistance of the tube

R_L = The plate load resistance of the tube.

From the above formuli it is apparent that as the resistance of R_L decreases, the maximum operating frequency increases, but at the expense of voltage gain. (See circuit in Figure 1).

Another method of eliminating the shunting effects of stray capacitance is to make it a part of a resonant circuit. To do this R_L is replaced by an inductance. The inductance is resonated by the stray capacity (C_s) and an additional capacity (C_1 and C_2 shown in Figure 2 A).

The resonant circuit offers a high impedance for the tube's input and output circuits at the operating frequency. This produces a high amplifier gain. Notice that C_s is now part of the resonant circuit of the amplifier and no longer bypasses the desired signal.

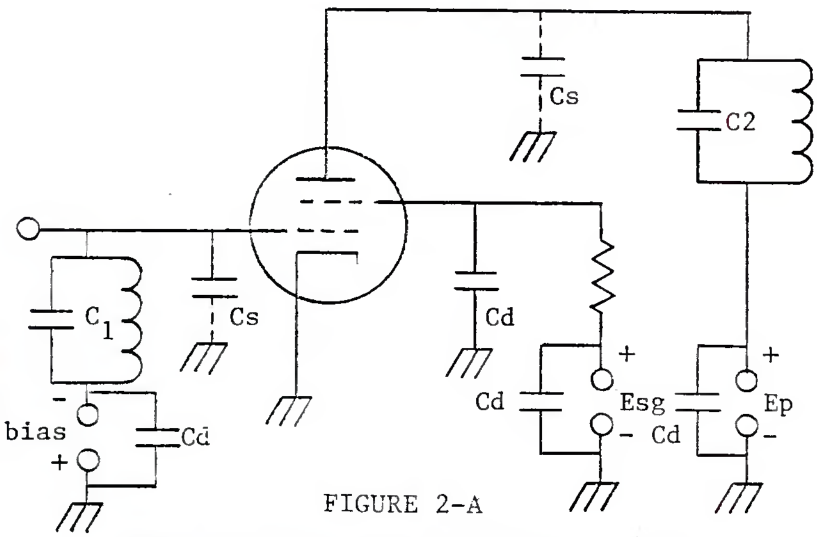


FIGURE 2-A

Circuit of an RF amplifier showing the input and output stray capacity and tuned circuits

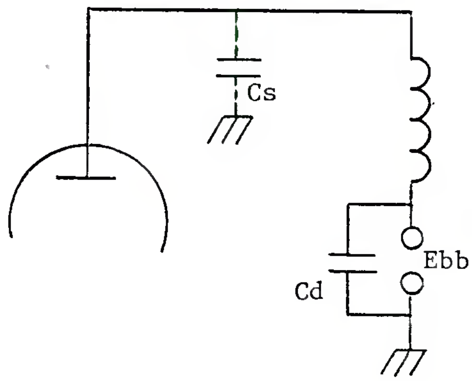


FIGURE 2-B

Plate circuit of higher frequency amplifier where C_s is the resonating capacity.

The scheme worked fine when 10 MH_z was the highest usable frequency. As higher frequencies were used several new problems became apparent. They were: skin effect, decreasing values of L and C required to resonante the circuit, and stray inductance.

REDUCING THE VALUE OF INDUCTANCE AND CAPACITANCE

The formula for resonant frequency is:

$$f_R = \frac{1}{2 \pi \sqrt{L C}}$$

Where: f_R = Resonant frequency in Hertz

L = Inductance in Henries

C = Capacitance in Farads

To increase the resonant frequency, L and/or C must be reduced. In the RF amplifier the value of the added C can be reduced until C_s is the only resonating capacity in the circuit. (See Figure 2-B).

The value of inductance is reduced by winding fewer turns on the coil and keeping the coil's diameter small. Eventually as the frequency increases the coil might have less than one turn or even be a straight conductor. The inductance of the straight conductor is determined by its length and diameter.

The longer the conductor, the greater its inductance will be.

The greater the area of the conductor, the smaller the inductance will be.

SOLVING THE SKIN EFFECT PROBLEM

Skin effect is a condition that causes RF currents to flow only on the surface of the conductor at higher frequencies. As the frequency of the RF increases, the RF current tends to flow closer to the surface of the conductor. At VHF TV and FM frequencies, the conducting layer is only a few thousandths of an inch thick. Thus the RF resistance of a conductor is much greater than the DC resistance. This necessitates the use of larger conductors with greater surface area for high power use at VHF frequencies. This will keep skin effect losses low. Silver plating is often used on VHF RF components to lower the RF resistance.

STRAY INDUCTANCE

We now have the stray capacity of the circuit resonating an inductor that consists of a large area conductor with few or no turns. This gives rise to the problem of stray inductance. The leads that connect the various elements of the tube to the amplifier circuitry now contain much inductance compared to the rest of the amplifier's circuitry. This inductance can act as:

(1) An RF choke which will reduce the RF output.

(2) Part of another, unplanned, resonant circuit with the stray capacity of the tube. This can cause the tube to have parasitic oscillations.

PARASITIC OSCILLATIONS

Parasitic oscillation can occur within the tube or can occur because of the tube and its external circuitry. They are stopped by several methods. The most common method is the losser resistance (also called the parasitic suppressor). It is a small value of resistance (usually less than 100 ohms) found in series with the plate, screen, or grid circuits of the tube. It lowers the Q of circuit that causes the parasitic oscillations and eliminates them.

A material called Eccosorb is also used in cavity type RF amplifiers to prevent parasitic oscillations. It offers resistance to the parasitic oscillations and can be in the form of hard blocks or various molded shapes, or thin flexible sheets. It is used in selected places in the RF path of the amplifier to lower the Q of the parasitic oscillation circuits and eliminate them.

Another consideration of operation at VHF frequencies is that unlike operation at lower frequencies, relatively pure lumped components of resistance, capacitance, and inductance are extremely difficult to produce. All the components will exhibit considerable values of resistance, inductance and capacitance.

Thus as frequency increases, lumped component resonant circuits get smaller and smaller (to reduce L and C); larger in diameter (to reduce skin effect); closer to the tube to reduce the effects of stray L; and there is great difficulty in predicting exactly what values of R, L, and C a component or circuit may have.

These problems can be managed in low power circuits but with high power circuits, arcs and shorts due to high DC and RF voltages become a problem. Larger size and spacing of components is a good start towards arc and short prevention, but this is in opposition to the smaller size and spacing dictated by the high frequency operation. Also in high power circuits, the unpredictability of the circuit values of R, L, and C make it difficult to control the vitally important parameters of dissipation, efficiency, and reliability of operation.

THE TRANSMISSION LINE CAVITY

One solution to the above problems is the resonant transmission line cavity amplifier. In this type of amplifier the tube becomes part of a resonant transmission line. The elements of these tubes are arranged to look like concentric coaxial transmission lines. The design of these tubes stresses low interelectrode capacity and low distributed inductance. The stray (interelectrode and distributed) capacity and inductance of the tube becomes part of the resonant transmission line. The resonant transmission line is physically larger than the equivalent lumped constant L-C resonant circuit operating in the same frequency. This larger physical size aids in solving the high power operation problems of skin effect losses, prevention of arcs and shorts, and reliable and predictable operation. Before we can study the transmission line cavity, we must review the basics of resonant transmission lines.

REVIEW OF RESONANT TRANSMISSION LINES

Any transmission line (parallel wire, coax, or the microstrip type used on printed circuits) has a characteristic impedance. If a transmission line is terminated in its characteristic impedance by a resistive load (Example: a 50 ohm resister terminating a 50 ohm line), a signal traveling down the line will be totally absorbed by the load and no reflection will result. If the impedance of the termination (Z_L) does not equal the impedance of the line (Z_o), or if Z_L does equal Z_o but it is not totally resistive, a signal sent down the line will not be totally absorbed by the termination. Some or all of it will be reflected back down the line to the source.

FOUR SPECIAL CASES OF RESONANT LINES

There exists four special cases of improper termination of a transmission line. They are:

(1) A quarter wavelength section with termination open

(2) A quarter wavelength section with termination shorted

(3) A half wavelength section with termination open

(4) A half wavelength section with termination shorted.

The symbol for wavelength is λ .

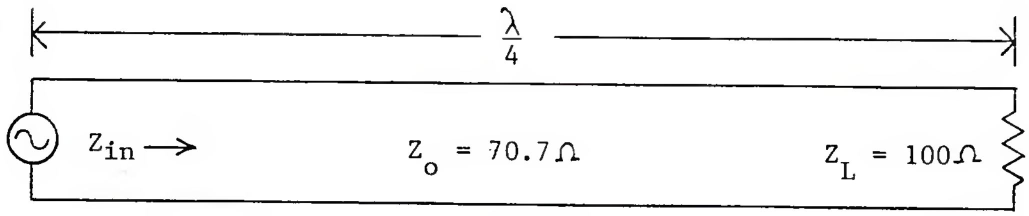
GENERAL RULES FOR RESONANT TRANSMISSION LINES

Two general rules exist for these four cases. They are:

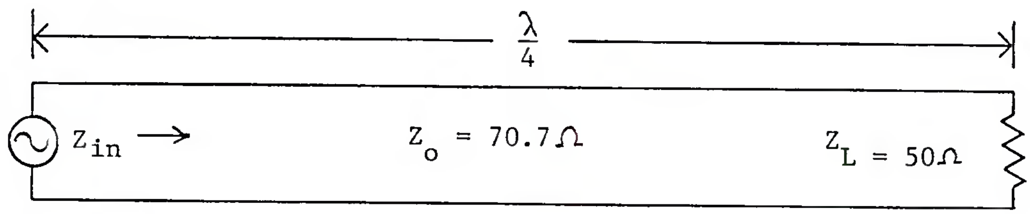
(1) A quarter wavelength of transmission line inverts impedance.

(a) If the Z_L is less than Z_o, then the input impedance of the line(Z_{in}) will be greater than Z_o. (See Figure 3)

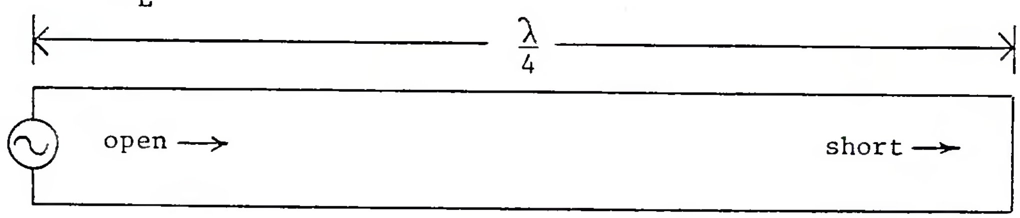
(b) If Z_L is greater than Z_o, then Z_{in} will be less than Z_o. (See Figure 3)



A. $Z_{in} = \dfrac{Z_o^2}{Z_L} = 50\Omega$

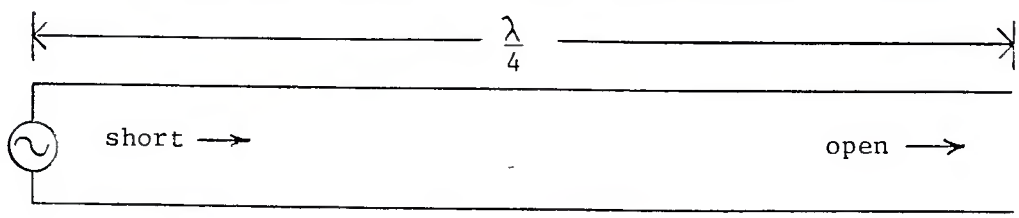


B. $Z_{in} = \dfrac{Z_o^2}{Z_L} = 100\Omega$



C. A shorted termination yields an open source.

The source is equivalent to a parallel resonant circuit.



D. An open termination yields a shorted source.

The source is equivalent to a series resonant circuit.

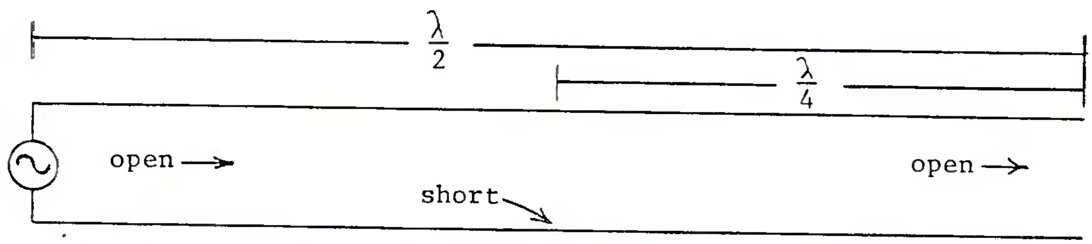
FIGURE 3 - Four examples of improper termination (Z_L) that shows the <u>inverting properties of a quarter wavelength of a transmission line.</u> The line used in Examples (A) and (B) had a characteristic impedance (Z_{in}) of 70.7 ohm, but the line impedance (Z_o) of A through D could be any value and still yield correct results using the formula:

$$Z_{in} = \frac{Z_o^2}{Z_L}$$

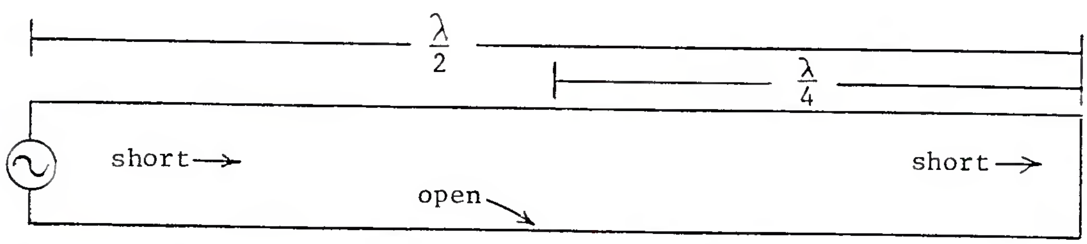
(2) A half wavelength section of transmission line repeats impedance.

(a) Think of it as two quarter wavelength sections in series. (See Figure 4 A and B).

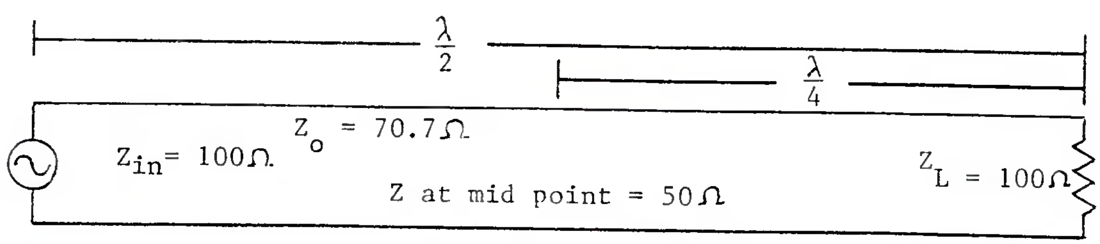
(b) The input impedance (Z_{in}) always equals the load impedance. (See Figure 4 C).



A. An open termination of a half wavelength section yields an open source. The source is equivalent to a parallel resonant circuit.



B. A shorted termination of a half wavelength section yields a shorted source. This is equivalent to a series resonant circuit.



C. A half wavelength line repeats impedance. At $\lambda/4$ from the termination

$Z_{mid} = \dfrac{Z_o^2}{Z_L} = 50\Omega$ $\lambda/4$ from this point (the source) $Z_{in} = \dfrac{Z_o^2}{Z_{mid}} = 100\Omega$

FIGURE 4 - Conditions of a half wavelength of transmission line. The Z_o of the lines in Figures A, B, C can be any value, but Figure C is shown in this example at Z_o = 70.7 ohms.

THE SHORTED QUARTER WAVELENGTH LINE

A shorted quarter wavelength transmission line has a high (almost open), purely resistive input impedance. Electrically it looks like a parallel resonant circuit. If the applied frequency is changed slightly so that the shorted line is no longer one quarter wavelength long, the input impedance drops and no longer remains purely resistive. (See Figure 6).

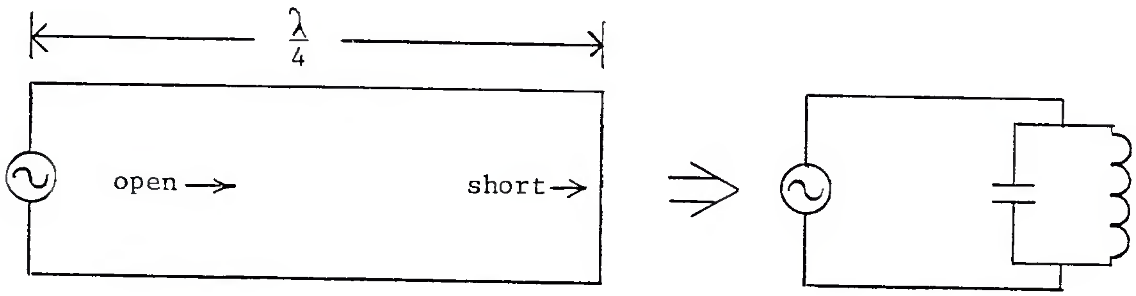
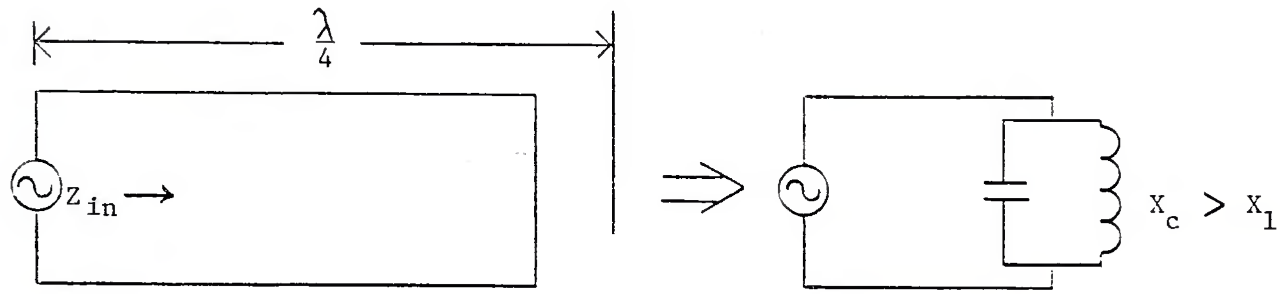


FIGURE 5 - A shorted, quarter wavelength line looks like a parallel resonant circuit.

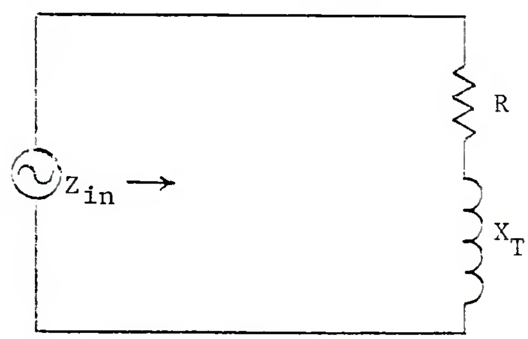
THE SHORTED TRANSMISSION LINE LESS THAN A QUARTER WAVELENGTH LONG

When operated at a frequency below that for which the shorted line is one quarter wavelength long, the physical length of the line at the new lower frequency will be less than one quarter wavelength. The impendance will be lower and the line will look inductive. Actually, the impedance will be a combination of resistance and inductance. As the applied frequency is lowered further, the resistance will become lower, the inductance will become greater, and the impedance will become smaller. (See Figure 6 A and C). This same effect is seen on a parallel resonant circuit when it is operated below resonance (See the Example in Figure 6).



A. The applied frequency is lower than the frequency for which the line is $\lambda/4$. The Z_{in} is inductive and resistive.

B. The equivalent circuit of A. A parallel resonant circuit is operated below resonance, X_c is greater than X_L and i_L is greater than i_c.



X_T is the total equivalent reactance. I_T can be inductive or capacitive. In this case it is inductive.

C. The equivalent circuit of A and B showing how Z_{in} appears.

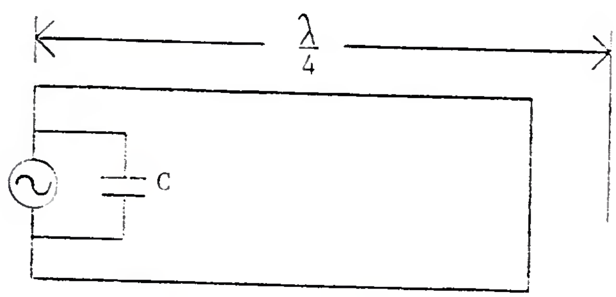
FIGURE 6 - The shorted line less than $\frac{\lambda}{4}$ and its eqivalent circuits.

In Figure 6-C, the equivalent circuit of the shorted line less than $\frac{\lambda}{4}$ and the parallel resonant circuit operated below resonance are both inductive. In Figure 6-B, if the capacitive reactance (X_c) is greater than the inductive reactance (X_L), than the current flow through the inductance (i_L) will be greater than the current through the capacitance (i_c).

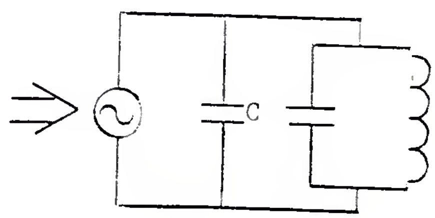
NOTE: The current i_L and i_c are 180° out of phase and would cancel at resonance, where $X_c = X_L$ and $i_c = i_L$. The generator supplies a small current to make up for circuit losses.

Below resonance where i_L is greater than i_c, the currents do not cancel and the generator's current is equal to that value of i_L not cancelled by i_c. To solve this problem and reresonate the circuit, we need only to make X_L equal to X_c.

In Figure 7, the circuits shown in A and B (in both cases the applied frequency is lower than the resonant frequency) are resonated by adding parallel capacity. In Figure 7-B, this lowers X_c to make it equal to X_L. In Figure 7-A, the shorted line is physically less than $\frac{\lambda}{4}$, but it has been electrically lengthened to $\frac{\lambda}{4}$ by the parallel capacity and is again resonant.



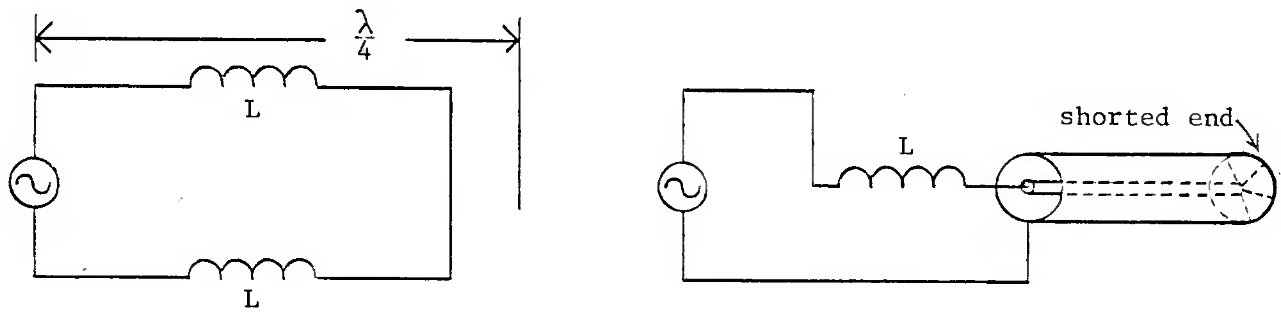
A. Capacitance (C) is added to electrically lengthen the line to $\lambda/4$ (resonate it).



B. Capacitance (C) is added to lower X_c and make it equal to X_L and resonate the circuit.

FIGURE 7 - Applied frequency is lower than resonant frequency and capacitance is added to resonate the circuit.

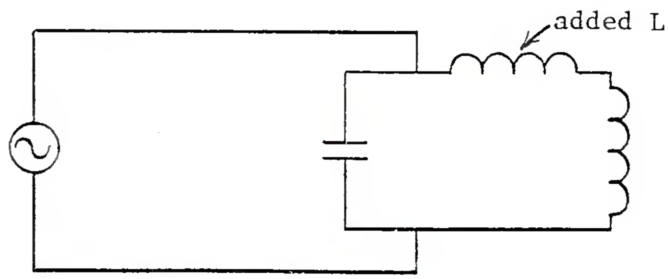
Another approach to resonating a circuit where the applied frequency is lower than the resonant frequency is to add a series inductance. In Figure 8-B, a small amount of series inductance is added to increase the X_L and make it equal to X_c. In Figure 8-A, the series inductance (or inductances in the case of a balanced line) electrically lengthen the physically short line to $\frac{\lambda}{4}$ and resonate it.



parrallel line

coaxial line

A. Adding series inductance somewhere in the physcially short line to electrically lengthen it and cause it to resonate.



B. Inductance is added to increase X_L and make it equal to X_c.

FIGURE 8 - When applied frequency is lower than resonant frequency, series inductance can be used to reresonate the circuit to this new lower frequency.

This concept is not new to many of you. How do you electrically lengthen an antenna that is physically too short? In an antenna system, series inductance (a loading coil) is used to lengthen an antenna whose length is not equal to $\frac{\lambda}{4}$ (vertical) or $\frac{\lambda}{2}$ (horizontal). See Figure 9.

Parallel, or shunt, capacity can also electrically lengthen an antenna that is physcially too short. In Figure 10, capacitive top hat loading electrically lengthens a vertical antenna. Shunt capacity can be used to lengthen a horizontal antenna, but it is less common.

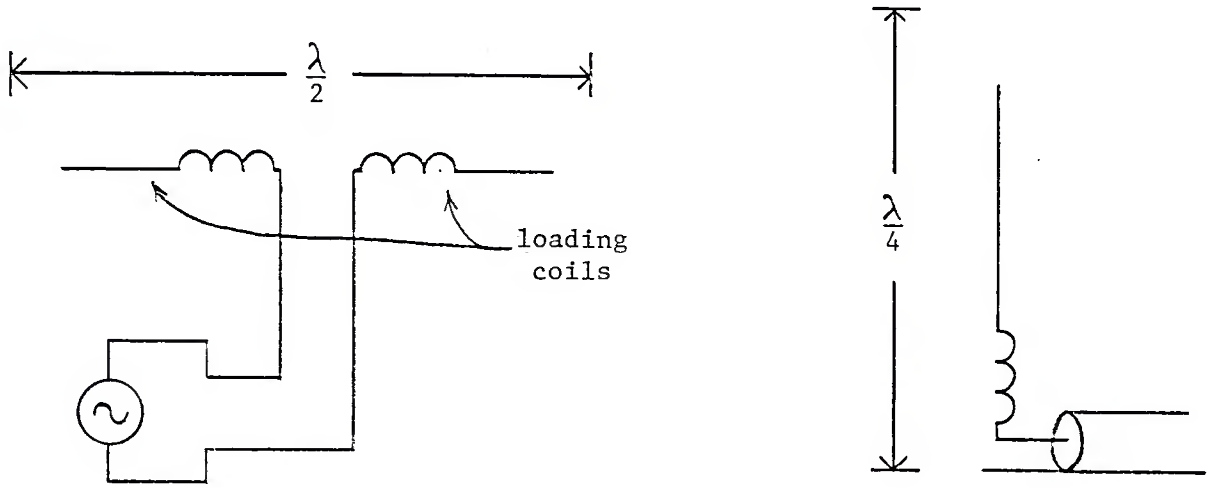


FIGURE 9 - Inductive loading electrically lengthens (and resonates) a physically short vertical and horizontal antenna.

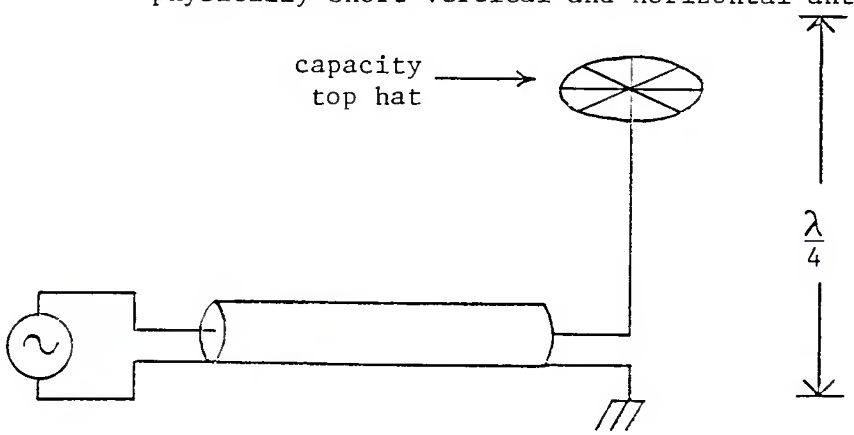


FIGURE 10 - A capacity top hat loading disc adds the shunt capacity that electrically lengthens the physically short antenna and resonates it.

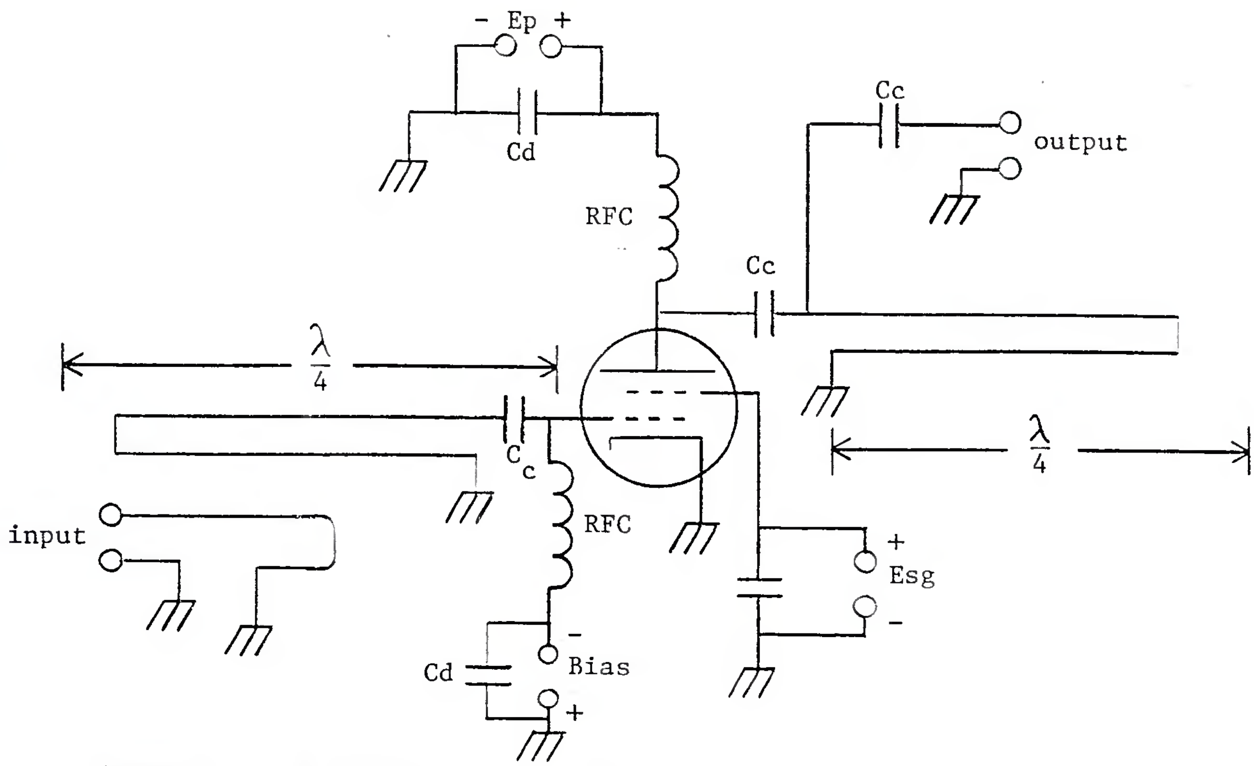


FIGURE 11 - A shorted, quarter wavelength transmission line amplifier.

C_c = Coupling capacitor

C_d = Decoupling capacitor

RFC = Radio frequency choke

In Figure 11, shorted transmission lines are used to resonate the inputs and outputs of this amplifier. Notice that the length of the lines are less than $\frac{\lambda}{4}$ but the tubes shunt input and output capacity and its series lead inductance will electrically lengthen and resonate the transmission lines. The input is shown inductively coupled, but it could just as easily have been capacitively coupled to the grid. The input could also have a lumped constant resonant circuit or a transmission line resonant circuit since its power level is low. The output coupling is capacitive, but it also could been inductive.

THE OPEN HALF WAVELENGTH TRANSMISSION LINE

The open ended half wavelength transmission line displays the same input characteristics as the shorted quarter wavelength transmission line. At $\frac{\lambda}{2}$ it acts like a parallel resonant circuit. It acts like an inductive/resistive circuit when it is shorter than $\frac{\lambda}{2}$, but greater than $\frac{\lambda}{4}$. As its wavelength progresses from $\frac{\lambda}{2}$ to just greater than $\frac{\lambda}{4}$, its impedance decreases and it gets more inductive. An open ended transmission line shorter than $\frac{\lambda}{2}$ can be electrically lengthened (brought to resonance at a lower frequency) by adding shunt capacity and/or series inductance.

THE OPEN HALF WAVELENGTH TRANSMSSION LINE AMPLIFIER

When incorporated into an amplifier circuit, the input may consist of a transmission line type resonant circuit or a lumped constant type resonant circuit. The lumped constant resonant circuit can be used at the input because of its lower power requirement.

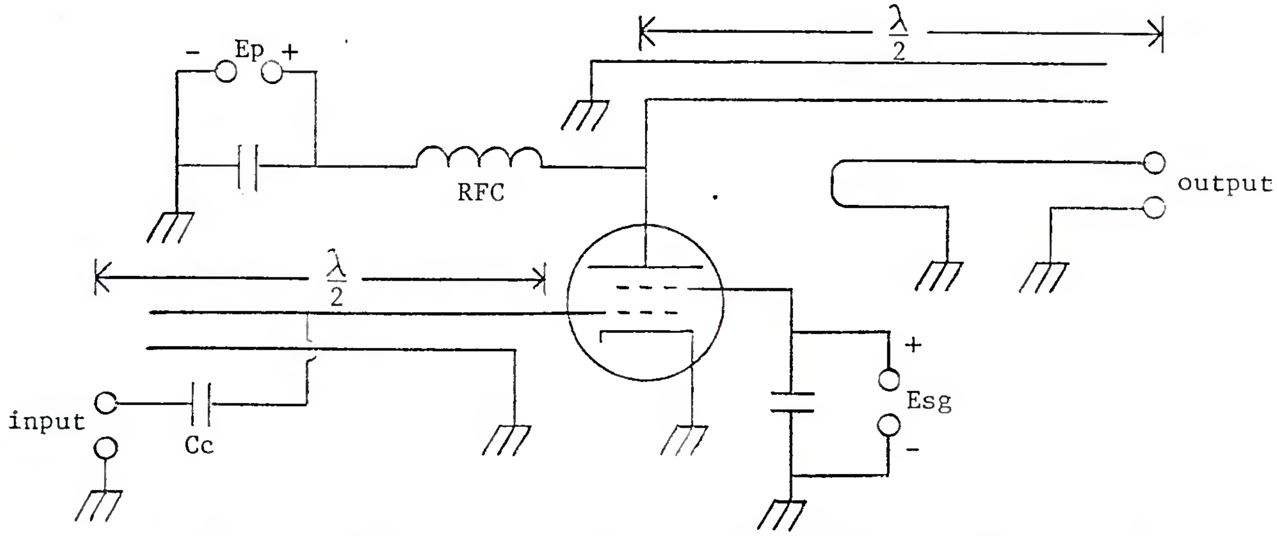


FIGURE 12 - A half wave open ended transmission line amplifier. The input and output can be inductively or capactively coupled.

The input and output can be either inductive loop coupled or capacitively coupled. The transmission lines used in this amplifier are shorter than $\frac{\lambda}{2}$. The stray inductance and capacitance of the tube becomes part of the resonant circuit and electrically lengthens (lower the resonant frequency) of the input and output transmission lines. (See Figure 12).

REVIEW OF COUPLED PARALLEL INDUCTORS

To understand one feature of the FM 2.5K through FM 20K FM transmitter RF power amplifiers, it is necessary to review inductively coupled, parallel inductors.

If two inductors are connected in parallel but not magnetically coupled, the total inductance will be equal to the formula:

$$L_T = \frac{L_1 \times L_2}{L_1 + L_2} \qquad \text{or} \qquad L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2}}$$

Assume each inductor is 1 uh. The total inductance will be 0.5 uh. (See Figure 13-A).

If two inductors are positioned so that there is an aiding magnet coupling, the inductance of each inductor will increase. This increased inductance is due to the mutual inductance provided by the magnetic coupling.

$$L_1' = L_1 + L_m \qquad \text{and} \qquad L_2' = L_2 + L_m$$

Where: L_m is the mutual inductance provided by the magnetic coupling.

If these two coupled inductors are placed in parallel (still magnetic aiding, the total inductance will be:

$$L_T = \frac{1}{\frac{1}{L_1 + L_m} + \frac{1}{L_2 + L_m}}$$

(See Figure 13-B)

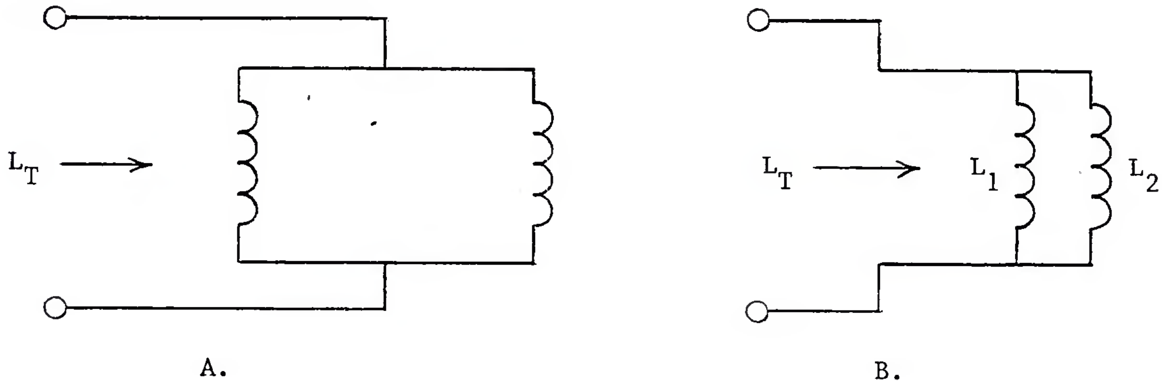


FIGURE 13 -(A) Two parallel 1 uh inductors without magnetic coupling.

$$L_T = 0.5 \text{ uh}$$

(B) Two parallel 1 uh inductors that have aiding magnetic coupling.

$$L_T = 0.55 \text{ uh}$$

If two parallel inductors are constructed so that their magnetic coupling can be changed, the total inductance can be varied over a small range.

INDUCTANCE OF A STRAIGHT CONDUCTOR

Every conductor has some value of inductance at VHF frequenceis. This inductance has a large effect on the circuit due to its high inductive reactance (X_L). $X_L = 2\pi F L$. A small diameter conductor a few inches in length may act as an RF choke. A simple rule exists to help us control this value of inductance. Remembering that at VHF frequencies, the skin effect causes most, if not all of the RF current to flow on the surface of the conductor. The rule is this:

(1) As the surface area of a conductor of given length increases, its inductance decreases. A large area conductor may be thought of as many smaller area conductors in parallel.

The inductance of the large area conductor is less than the inductance of the small area conductor because of the law of parallel inductors.

$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

(2) The inductance of a straight conductor is directly proportional to its length.

COAXIAL LINE FEATURES OF A TETRODE R.F. POWER AMPLIFIER TUBE

THE ANODE (PLATE)

The plate resembles a copper cup with half of the plate contact ring welded to the mouth and the cooling fins silver soldered or welded to the outside of the cup. (See Figure 14 and Figure 15).

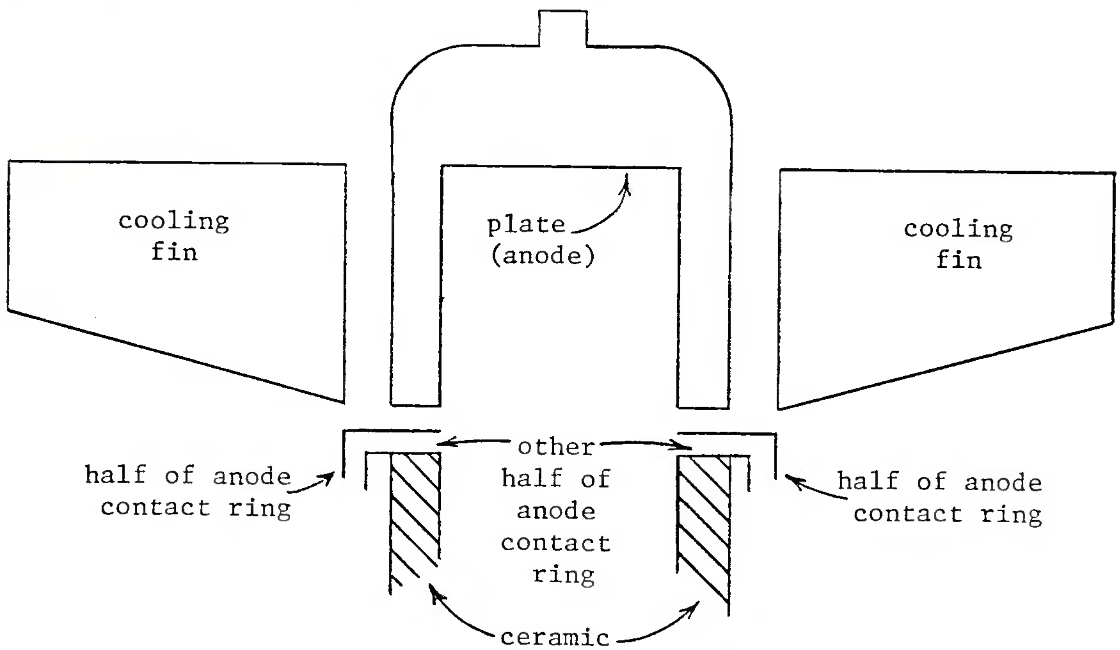


FIGURE 14 - Cut away view of the anode structure.

The other half of the anode contact ring is bonded to the base ceramic spacer. It fits into the half of the anode contact ring fastened to the plate structure, and the two halves are welded together. This ceramic spacer is the same ceramic that is shown above the screen contact ring in Figure 16.

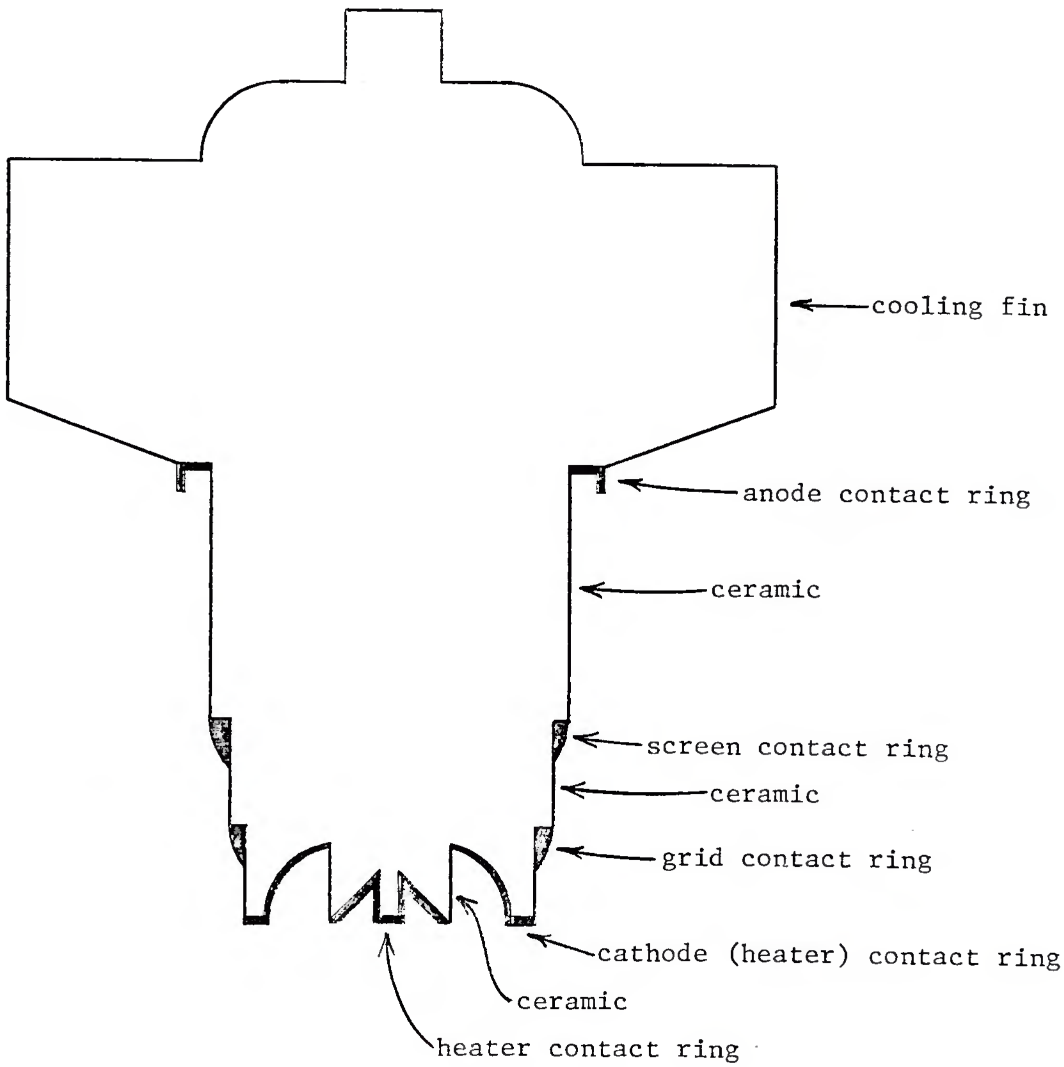


FIGURE 15 - A cutaway view of the exterior of a tetrode RF Power amplifier of the type used on F.M. transmitters.

THE SCREEN STRUCTURE

The screen grid consists of many vertical supports fastened to a metal base cone. The other end of the metal base cone fastens to the screen contact ring. The inductance of the individual vertical supports is reduced by building the screen grid of many of them in parallel. The vertical supports are held rigid by horizontal rings welded to them and a metal cap on the top of the assembly. The screen contact ring, metal base, and metal base cone also functions to reduce lead inductance and RF resistance due to skin effect. (See Figure 16).

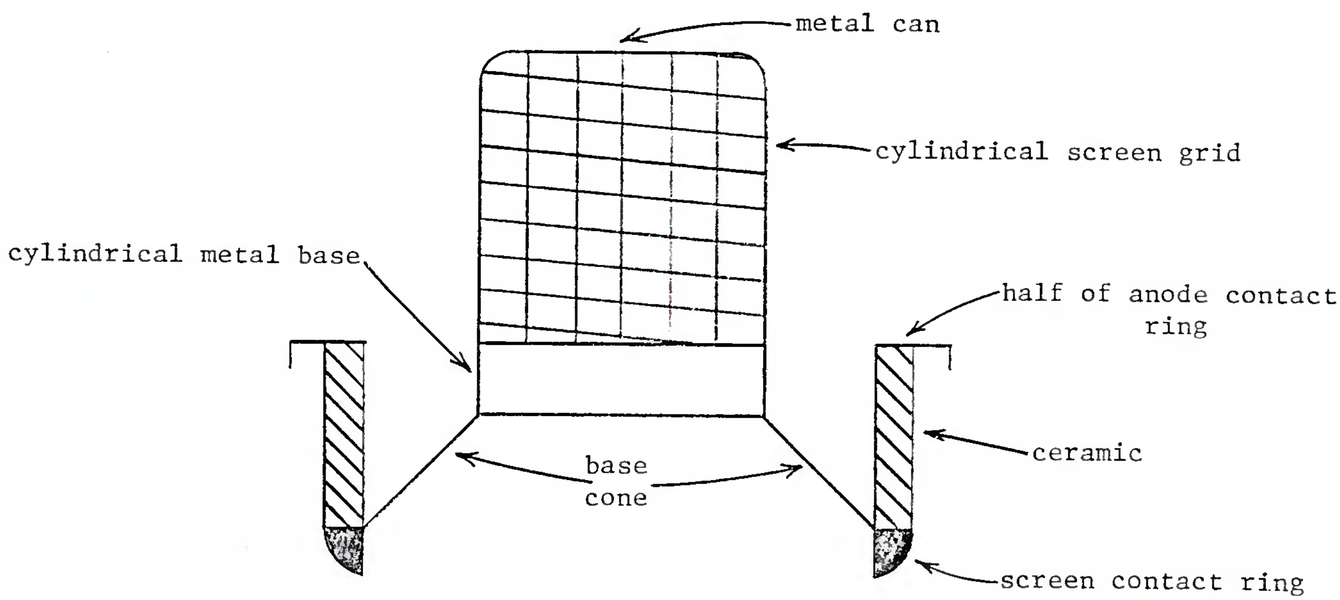


FIGURE 16 - The screen grid assembly

A cut away view of the plate circuit and the screen circuit in Figure 17 shows a concentric construction that resembles a coaxial transmission line.

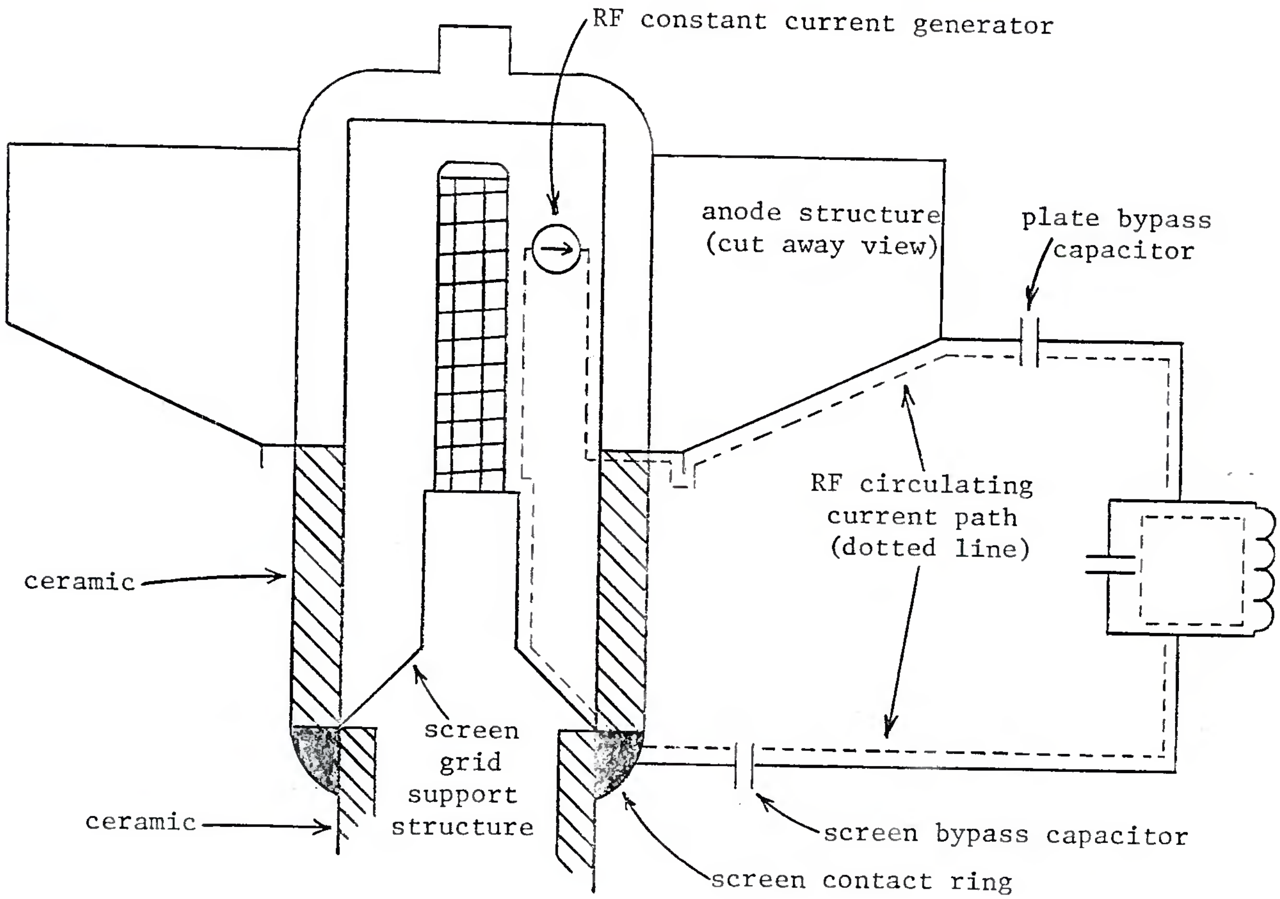


FIGURE 17 - Showing the plate and screen assembly and RF circulating current path (dotted line)

Consider that the output RF current is generated by an imaginary current generator between the plate and screen grid. The RF current travels along the inside of the plate structure on its surface (skin effect), through the ceramic at the bottom of the anode contact ring, around the anode contact ring, across the bottom of the fins, and to the band around the outside of the fins. From here it flows through the plate bypass capacitor to the RF tuned circuit and load, and returns to the screen grid. The return current travels through the screen bypass capacitor, then through the screen contact ring, up the cone, and up the screen grid to return to the imaginary generator. The screen grid has RF current returning to it but due to its low impedance, the screen grid is at RF ground potential. The RF current generator appears to be feeding an open ended transmission line consisting of the anode (plate) assembly, and the screen assembly. The RF voltage developed by the anode is due to the plate impedance (Z_p) presented to the anode by the resonant circuit and its load.

The control grid assembly and the cathode assembly are also cylindrically constructed and concentric. The control grid assembly is constructed similarly to the screen grid and is slightly smaller than it. Figure 18 shows the screen grid, control grid, and the cathode assemblies as they are placed in the tube.

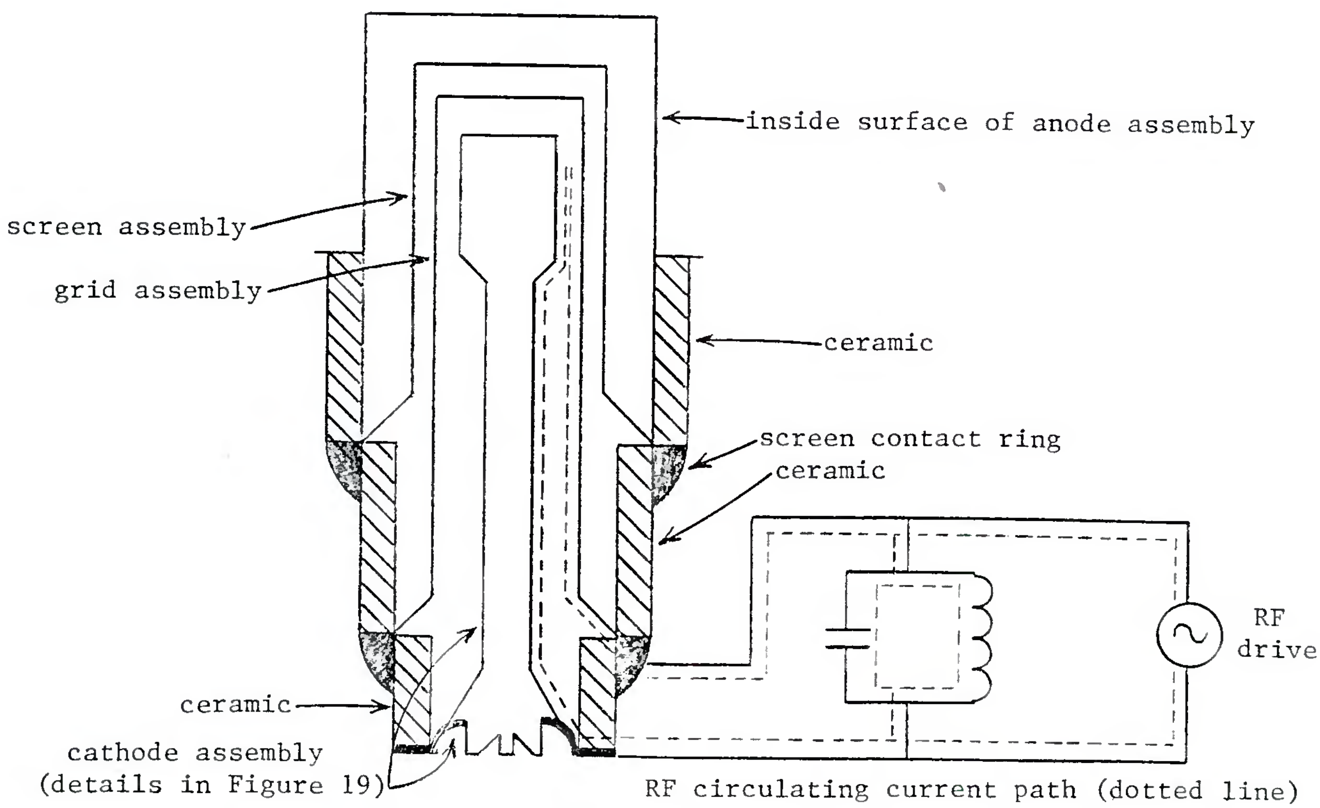


FIGURE 18 - Showing details of assembly of grids and cathode components, and the simplified RF input circuit (bias circuit not shown)

In Figure 18, an RF generator (The RF driver output) feeds a signal to the grid cathode circuit. The grid cathode assembly resembles a transmission line whose termination is the RF resistance of the electron stream within the tube.

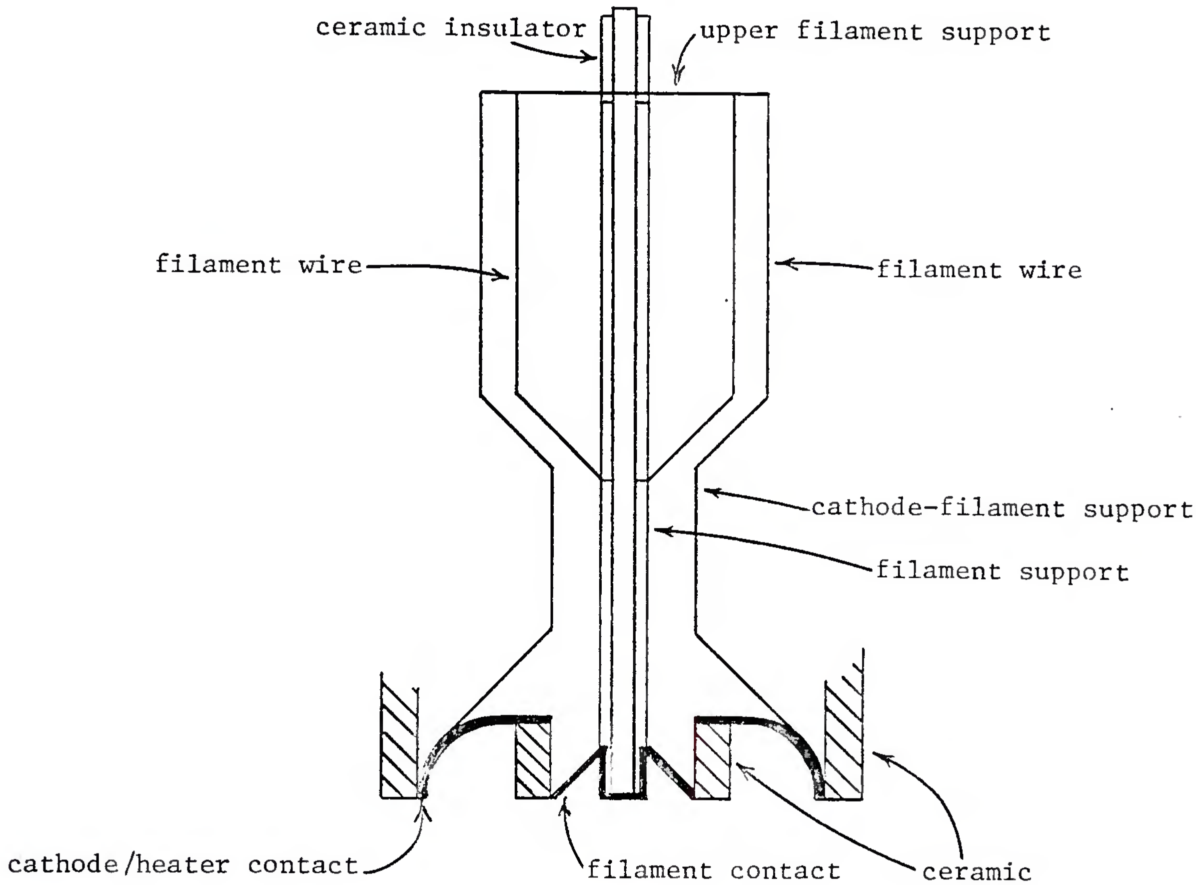
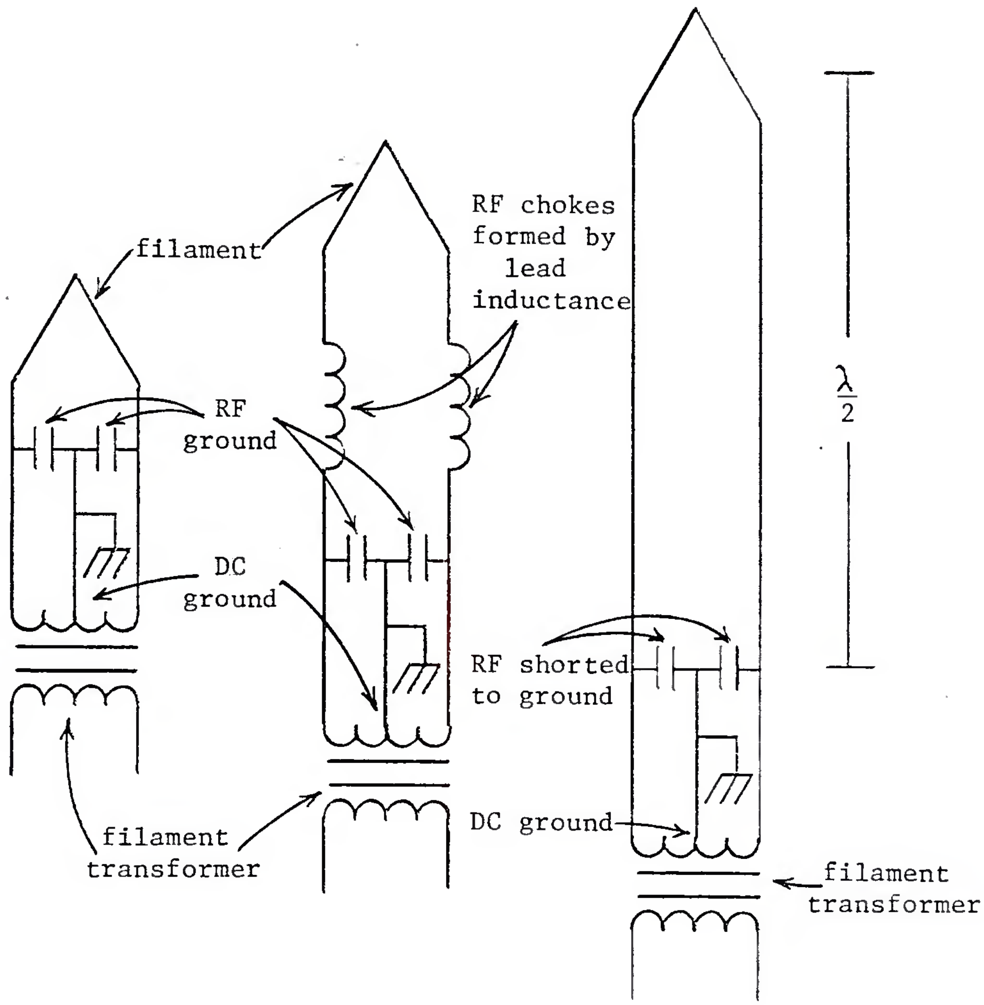


FIGURE 19 - The cathode assembly. The filament assembly consists of many parallel loops of wire supported at the top. Both sides of the filament supply feed the bottom of each loop.

The details of the cathode assembly are shown in Figure 19. The outer ring (the cathode heater contact) is the inner conductor of a coaxial transmission line formed by the cathode and control grid assemblies. The other side of the filaments is returned down the center of the cathode assembly.



A. Grounding the cathode below 30MHz

B. Grounding the cathode above 30MHz

C. Grounding the cathode via a λ/2 transmission line

FIGURE 20 - Bypassing the cathode

When operating an amplifier stage grounded cathode, feeding the RF into the grid, RF current flows into the cathode and grid circuits, but the cathode must have a low impedance (and thus low RF voltage).

Below 30 MH_z (Figure 20-A), the cathode can be grounded by simply bypassing the filament connections with capacitors.

Above 30 MH_z, the same technique does not work well because of the stray inductance of the filament leads. Notice in Figure 20-B the filament leads appear as RF chokes preventing the cathode from being placed at RF ground potential. This causes negative feedback and effects the efficiency of the input and output circuits.

In Figure 20-C, the cathode circuit is incorporated into a half wavelength transmission line. The line is shorted to ground by large values of capacitance one-half wavelength from the center of the filament (at the filament voltage feed point). This short is repeated one-half wavelength away at the cathode (heater assembly) and effectively places it at ground potential.

Since half wavelength bypassing is bulky and expensive, the selection of proper values of inductance and capacitance in the filament/cathode circuit can create an artifical transmission line that simulates the one-half wavelength shorted line shown in Figure 20-C. If Figure 20-B is observed, the inductance and capacitance can resemble an artifical transmission line of one-half wavelength, if the values of L and C are properly selected.

If this still does not make sense to you, remember that a half wavelength shorted transmission line appear to be a series resonant circuit. Now if proper values of inductance and capacitance are selected, does each side of Figure 20-B resembles a series resonant circuit?

REMEMBER: A series resonant circuit offers minimum impedance at resonances.

If you have a VHF tube type amplifier whose grid/cathode circuit is not the concentric transmission line type, you can remember selecting various lengths, widths (sizes) and numbers of conductors (inductors in this case) connecting the cathode to ground. You have bent, shaped, and changed those conductors (fine tuning values of L and C) until the amplifier has the proper efficiency of operation, grid current, RF input driver, and etc. You were really resonating the cathode circuit to place it at RF ground. To resonate the grid circuit much of these same types of bending, shaping, changing, and resonating adjustments took place. This is done to make the grid circuit operate at a high RF potential.

Most of these adjustment on your transmitter were performed by Factory Test and/or Field Service personnel. They need not be redone unless the tube manufacturer changes the tube internally (we'll notify you if this happens), or if you must change the transmitter's operating frequency. If the operating frequency must be changed, you should notify us and get Field Service assistance to perform this change.

THE HALF WAVELENGTH CAVITY (FM 2.5K THROUGH FM 20K)

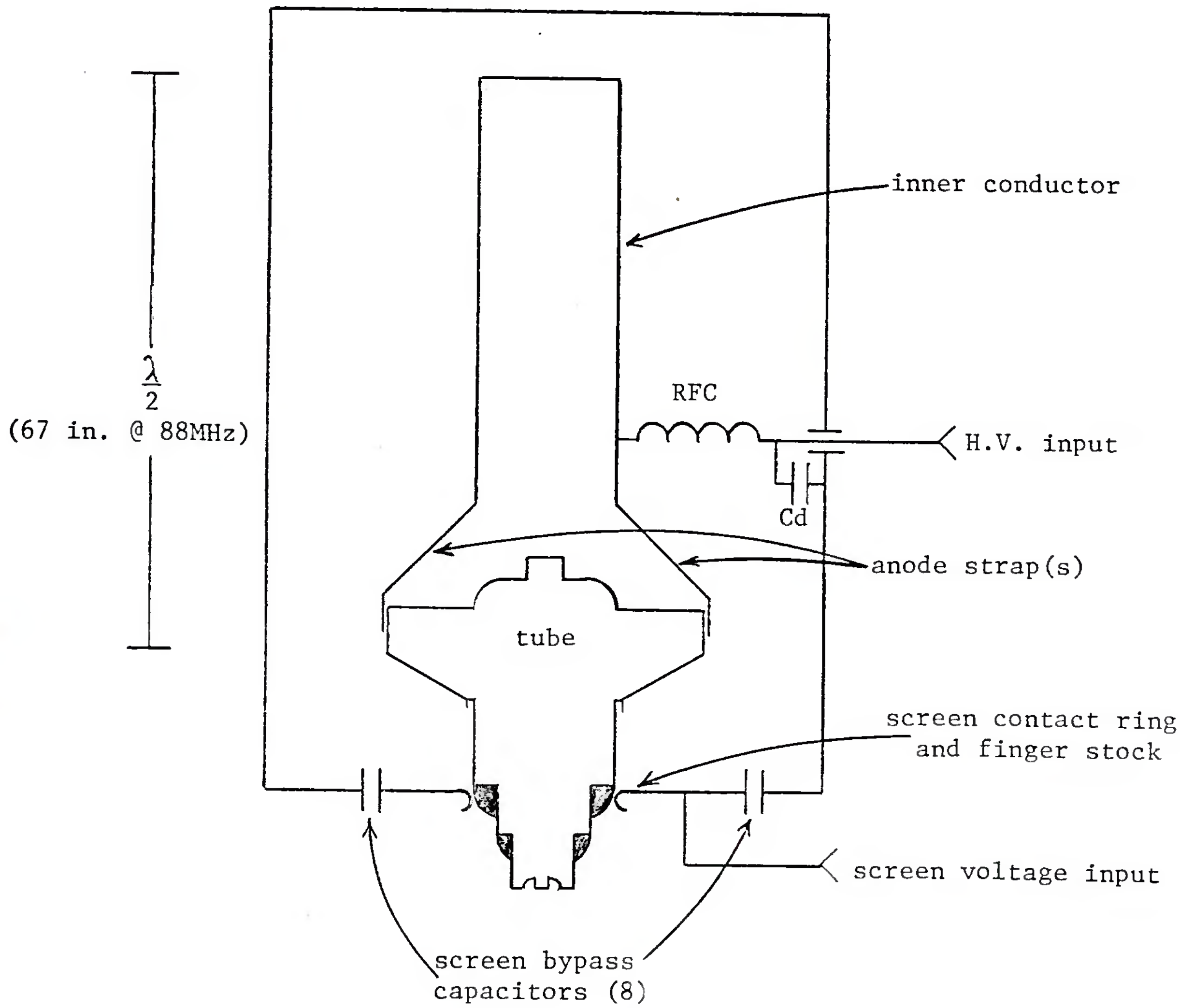


FIGURE 21 - A half wavelength cavity

This cavity (Figure 21) appears as a half wavelength circuit with the tube's anode and a silver plated brass pipe serving as the inner conductor, and the cavity box serving as the outer conductor. The transmission line is open at the far end and repeats this open condition at the tube. Remember that one half wavelength of transmission line repeats impedance. The line appears to be a parallel resonant circuit.

The circuit shown above was calculated for 88 MH_z. The inner conductor is 67 inches high. To allow room for the open condition at the top and the space for the input circuitry at the bottom, the cavity box would have to be almost eight feet tall. This size is too large for a practical transmitter and does not take tuning or operation at any other frequency between 88 MHz and 108 MHz into account.

If a graph of RF voltage and current and impedance were drawn for the inner conductor of the transmission line and the anode of the tube (See Figure 22), the plate inpedance of the tube would be many thousands of ohms. The plate's RF current would be extremely small and its RF voltage would be very large. Arcing would become a problem and the high plate impedance would make the amplifier operate inefficiently.

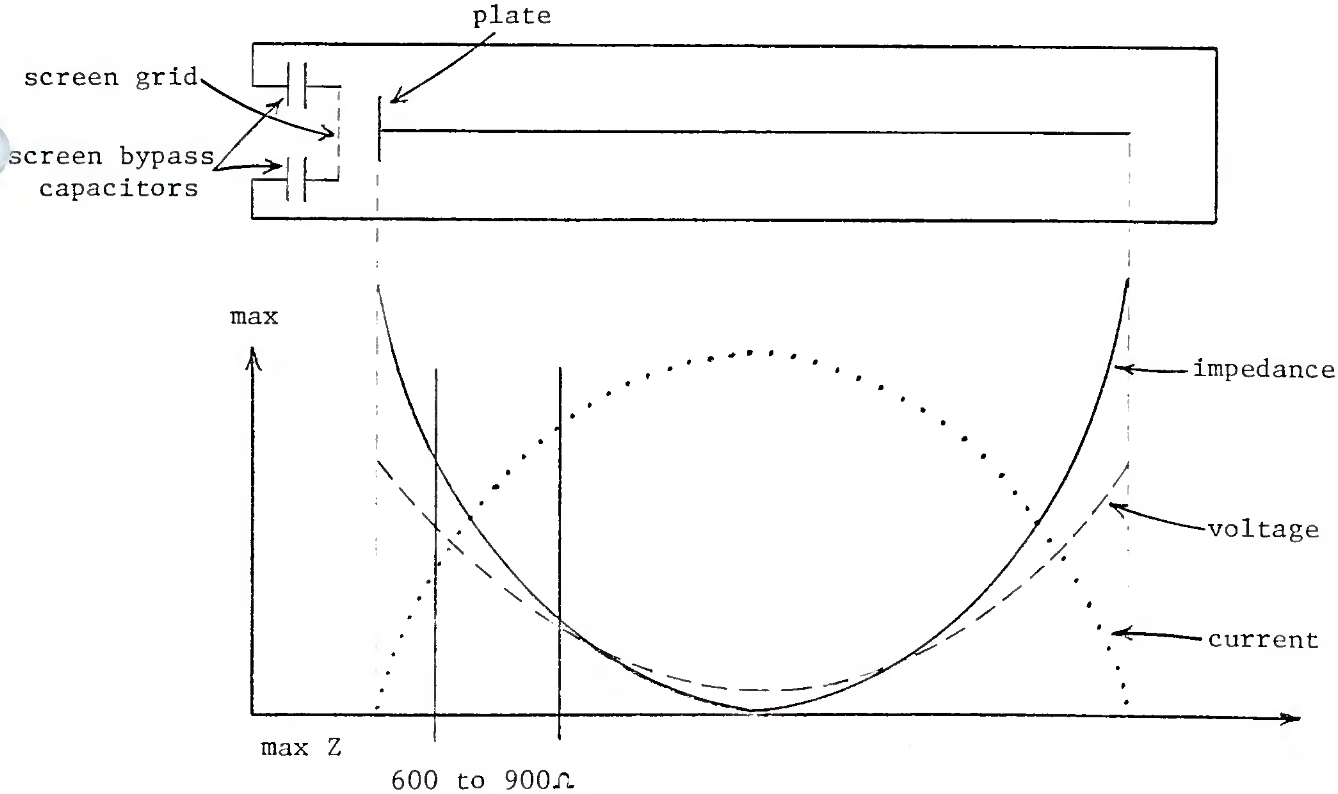


FIGURE 22 - Graph showing distribution of RF voltage, current, and impedance along the plate inner conductor.

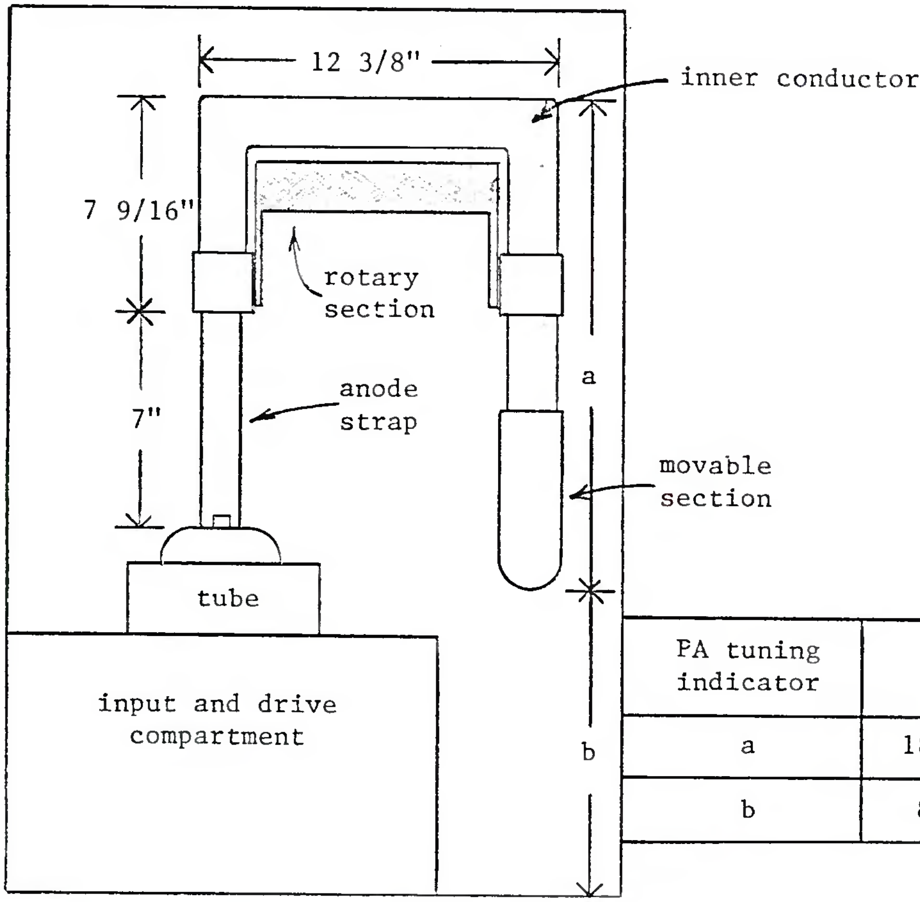
In Figure 22 there exists an area between the anode and the quarter wavelength short location where the impedance would be ideal for the anode of the tube (typically 600 to 800 ohms). To achieve this ideal plate impedance, the inner conductor should be less than one-half wavelength in physical length (physically foreshortened) and electrically resonated (electrically lengthened to one-half wavelength).

> Some engineers prefer to talk about physically foreshortening the line so that the shorter length resonates at the desired (lower) frequency. I prefer to speak of electrically lengthening the physically short line to be electrically one-half wavelength at the desired (lower) frequency. I believe this approach helps make clear the process of resonating the line.

If the line length were changed to operate at different frequencies, the plate impedance would also change because of the new distribution of RF voltage and current on this new length of line. The problem of frequency change now becomes twofold: (1) Change the length of the line to resonate it, and (2) keep the plate impedance of the tube constant for good plate efficiency (plate efficiency explained later under electrical parameters).

To solve the problems of operation at different frequencies while keeping the plate impedance constant, two forms of coarse tuning and one fine tune (plate tune) provisions are built into the cavity.

Lets explore the actual configuration of the cavity and explain the methods used to solve the problems of physical size, operating frequency, plate impedance, and the coarse and fine tuning arrangement. Figure 23 shows the tube and its plate line (inner conductor). The inner conductor is bent into a "U" shape to reduce the cavity height.



PA tuning indicator	000	max
a	18 1/16	13 3/4
b	8 1/16	12 3/8

FIGURE 23 - The configuration of the halfwave cavity

With the movable extension fully extended (plate tune indicator 000) the inner conductor measures 38 inches, and the anode strap measures 7 inches. The path from the anode strap to the inside surface of the tube's anode (along the surface due to skin effect) is estimated to be about 8 inches. This makes the inner conductor's maximum possible length about 53 inches. This is too short to be a physical half wavelength at any F.M. frequency. The length of a half-wave length line is 54.7 inches at 108 MH_z and 67.1 inches at 88 MH_z.

The two coarse tuning arrangements, the fine tuning arrangement, and the tube's output capacity resonate (electrically lengthen the physically foreshortened line) the plate line to the exact operating frequency. This process, along with proper loading, determines the proper plate impedance and therefore the efficiency.

ELECTRICALLY LENGTHENING THE PLATE LINE

THE STRAY CAPACITY

The output capacity of the tube is the first element that electrically lengthens the line. A halfwave transmission line that is too short offers a high impedance that is resistive and inductive. The tube's output capacity resonates this inductance and the detrimental effects of the output capacity are eliminated.

Another stray capacity that will electrically lengthen the line is the capacity between the movable section (the plate tune) and the cavity box (the outer conductor).

THE ANODE STRAP (COARSE TUNING PROVISION)

The anode strap has much less cross sectional area than the inner conductor of the transmission line. It therefore has more inductance than an equal length of the inner conductor. Thus the anode coupling strap acts as a series inductance and electrically lengthens the plate circuit.

At low frequencies, one narrow strap is used. This high inductance lengthens the plate circuit more. At the mid F.M. frequencies, one wider strap is used. This provides less inductance than the narrow strap and does not electrically lengthen the plate circuit as much. At the upper end of the F.M. band, two anode straps are used. This parallels the inductance of the anode straps (lower total inductance) and thus electrically lengthens the plate circuit even less.

This coarse adjustment gives three line lengths to choose from.

THE ROTARY SECTIONS

At the time of this writing there are two theories of what the rotary section does. I shall present both.

THE ROTARY SECTION AS A VARIABLE CAPACITOR

The main portion of the plate resonant line and the rotary section can be thought of as a single transmission line section with a larger area conductor regardless of the position of the rotor.

The rotary section can be thought of as a variable capacitor in which the capacity is greatest when the rotary section is closest to the cavity box (outer conductor) and least when it is furthest from the outer conductor. This shunt capacity would electrically lengthen the line and lower the resonant frequency. The amount of frequency change would depend on its position.

THE ROTARY SECTION AS A VARIABLE INDUCTOR

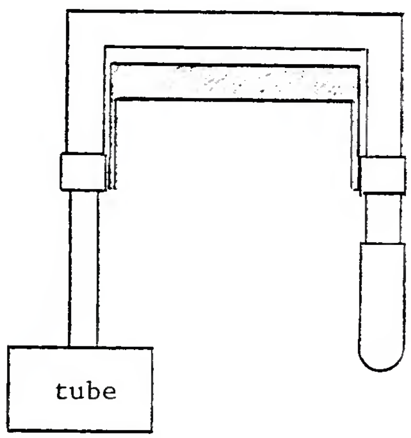
The main section and the rotary section of the plate resonant transmission line can be thought of as parallel inductance.

RF current flows in the same direction in the main transmission line and the rotary section, and thus their magnetic fields would aid.

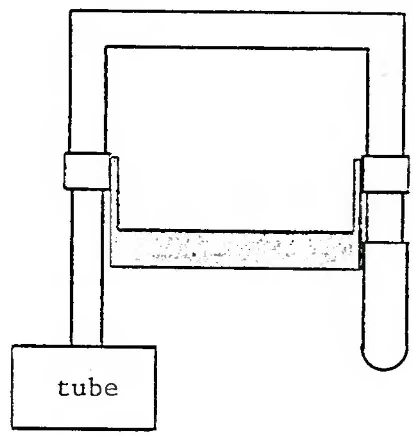
When the rotary section is at maximum height, the magnetic coupling between the main sections of transmission line and the rotary section is at maximum. Due to the relatively large mutual inductance provided by this close coupling, the total inductance of these parallel inductors would increase. This electrically lengthens the transmission line and lowers its resonant frequency. (See Figure 24-A).

When the rotary section is at minimum height, the magnetic coupling between these two parts of the inner transmission line is minimum. This reduced coupling lowers the mutual inductance which lowers the total inductance of the parallel combination. The reduced inductance does not electrically lengthen the line as much and it therefore operates at a higher resonant frequency. (See Figure 24-B).

The rotary section provides an infinite number of coarse setting for the various operating frequencies.



(A) The rotary section at maximum height



(B) The rotary section at minimum height.

FIGURE 24 - The positions of the movable section.

THE PLATE TUNING ASSEMBLY

The movable plate tune assembly is at the end of the plate inner transmission line. It is moved up and down, changing the physical length of the inner conductor by about 4 11/16 inches. It is linked to the plate tuning knob and provides a fine tuning adjustment for the cavity.

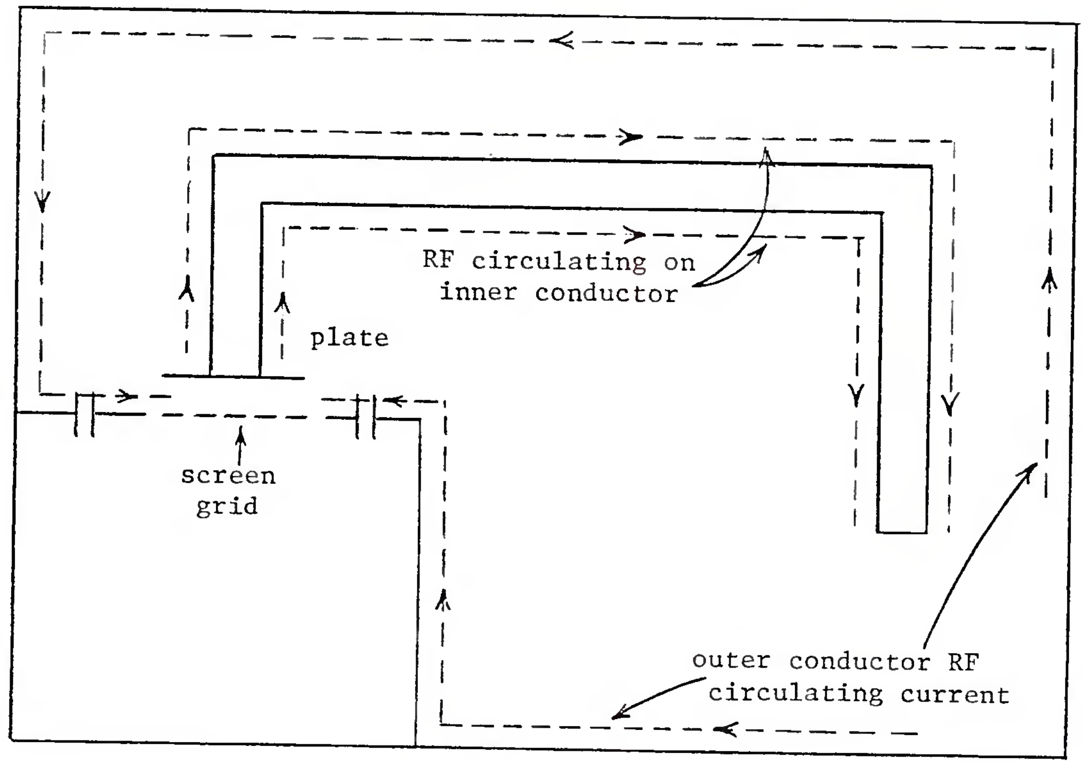


FIGURE 25 - RF circulating currents as a result of the imaginary RF current generator located between the plate and the screen grid. The direction shown for current flow is arbitrary (one-half cycle later it will reverse).

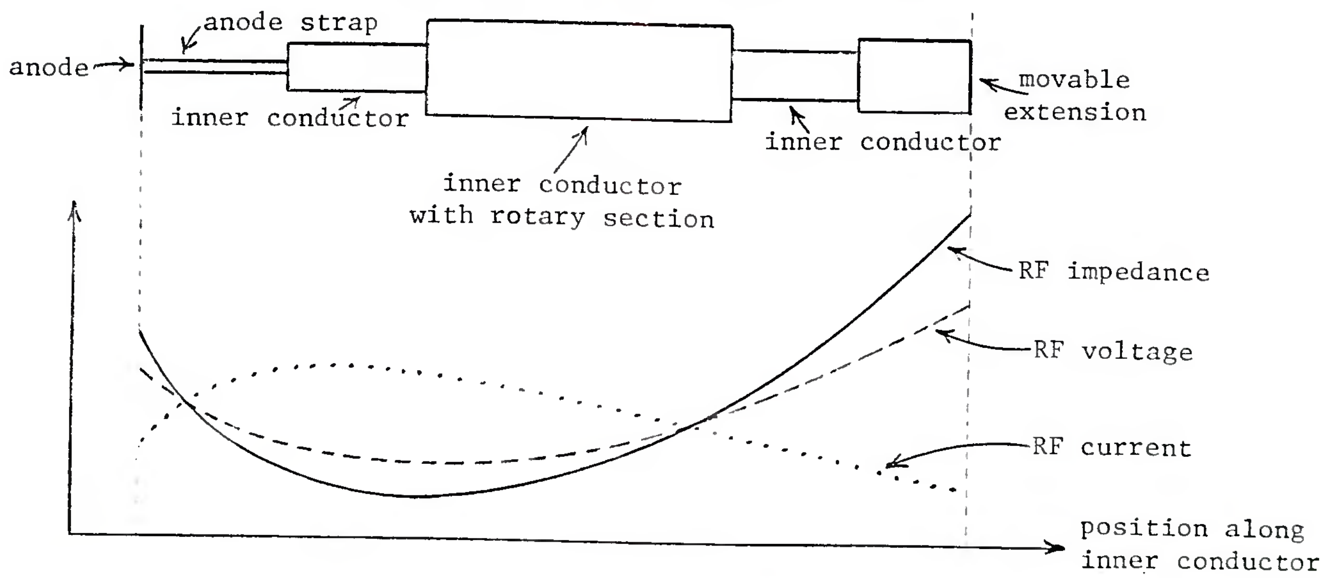


FIGURE 26 - Graph of RF current, voltage, and impedance for the cavities actual inner conductor.

THE RF CIRCULATING CURRENTS

CIRCULATING CURRENTS IN THE INNER CONDUCTOR (PLATE CIRCUIT)

Figure 25 shows the cavity RF circulating currents. The circuit impedance reflected back from the resonant circuit to the plate screen circuit of the tube is 600 to 800 ohms. RF current leaves the plate and flows down the electrical half wavelength plate inner conductor. When the current reaches the far end of the plate line it can go no further. The current flow is stopped and a high RF voltage is developed between the cavity box (outer conductor) and the end of the inner conductor. (See Figure 25). As with any other open terminated transmission line, the high RF voltage developed at the end of the line pushes (reflects) the RF current back down the line to the plate. This is the RF circulating current, the same as would be found in a conventional L-C tank circuit. If no load were placed on the resonant circuit it would have an extremely high Q. The circulating currents would gradually dampen out over several cycles if the plate-screen circuit were to receive only one pulse from the grid

NOTE: As with any other transmission line RF currents will flow in equal magnitude and opposite directions on the inner conductor and the outer conductor. We will study the RF circulating currents in the outer com dctor shortly. The inner conductor is used to determine the resonant frequency and determines where the load is coupled into it.

COUPLING THE LOAD

To couple energy out of the cavity two methods can be used. They are inductive coupling and capacitive coupling.

Capacitive coupling must take place at a maximum RF voltage point, at the far end of the line in this case. Inductive coupling must take place at the maximum RF current point. It is approximately one-quarter wavelength from the end of the inner conductor. (See Figure 26). In this cavity the two coarse tuning adjustments are located just before and after the place on the line where the inductive output coupling occurs. (See Figure 27). By proper combination of these two coarse tuning controls, the maximum current point is placed exactly over the output coupling point.

At the far end of the plate line, RF current does not go quite to zero. RF voltage and impedance never get quite to maximum due to the capacity between the end of the line and the cavity box (outer conductor). This also has the effect of physically foreshortening (electrically lengthening) the line.

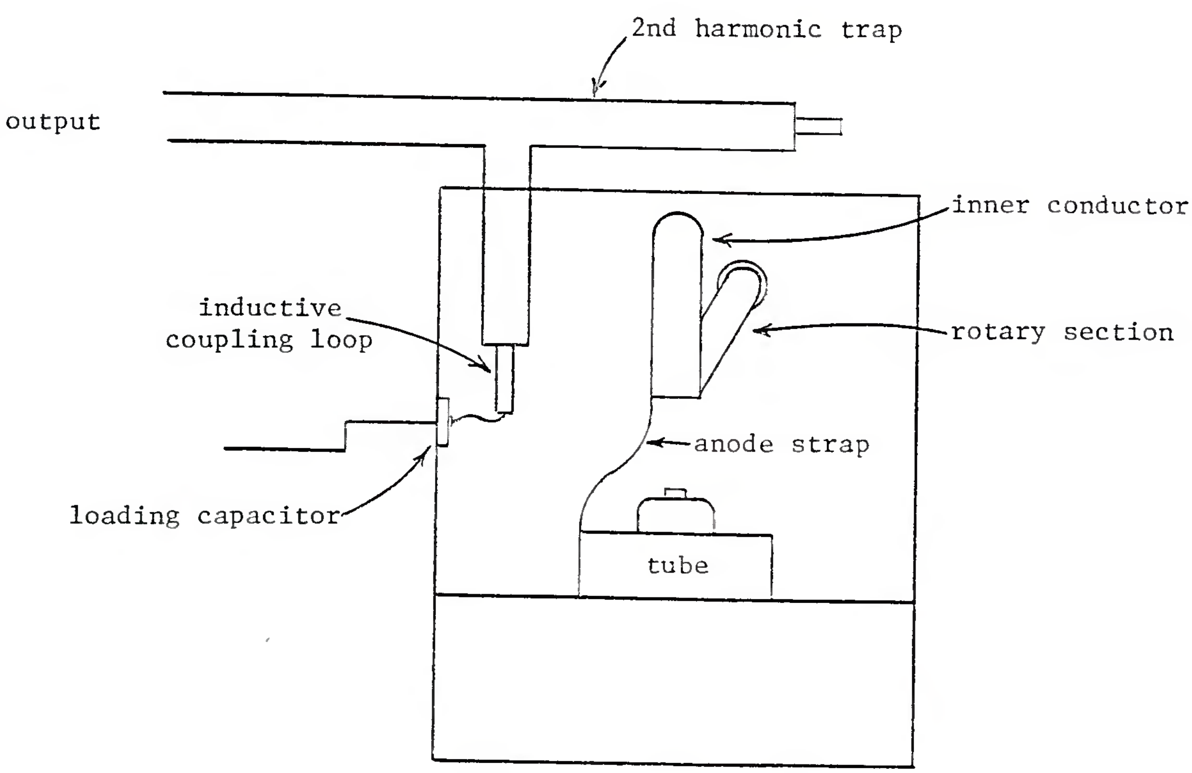


FIGURE 27 - Showing side view of cavity, and the location of the inductive coupling loop

THE CIRCULATING CURRENTS AND Q

The amount of cavity RF circulating current is directly dependent on the loaded Q of the cavity and is usually much higher than the RF output current or the RF plate current.

$$Q = \frac{Z_p}{X_L} \quad \text{and} \quad i_{circulating} = i_p \times Q$$

Where: $i_{circulating}$ = The cavity RF circulating current

i_p = The plate RF output current.

X_L = The inductive reactance required if the cavity resonant circuit had lumped constants of L and C.

This will be dicussed later under electrical parameters.

RF CIRCULATING CURRENTS IN THE OUTER CONDUCTOR

When current flows on one conductor of a transmission line an equal magnitude and current flows in the opposite direction on the other conductor. This means that a large value of RF circulating current is flowing in the cavity amplifier's outer conductor (the cavity box). All of the outer conductor's circulating currents start out at and return to the screen grid.

The back access panel (door) of the cavity is part of the cavity outer conductor and large values of circulating current flow through it, into it, and out of it. The amplifier must never be run with the back panel removed or any of the fasteners loose or damaged.

The mesh contact strap electrically connects the back panel to the rest of the cavity. If a fastener is loose or damaged, or the back panel is loose, or the mesh contact strap is damaged or defective, arcs will develope between the cavity box and that area of the back panel. Once an arc forms, the arced, pitted surface forms an insulator to the flow of RF currents. The arced surface can be cleaned but the surface must be flat to insure a good electrical contact. Any pit mark left by or under the mesh will cause a reoccurance of the arc.

THE SCREEN GRID'S RF PATH

The screen grid is connected to the screen contact ring on the tube base by a cone constructed inside the tube. The purpose of the cone is to greatly reduce the stray inductance and lower the RF resistance caused by skin effect. To take advantage of these parameters, the RF currents should flow evenly up all parts of the screen grid assembly. In Figure 28, one screen bypass capacitor is shown. This would cause all of the RF circulating current to flow at one point of the screen assembly and upset the field, increase skin effect losses, and value the apparent stray inductance would appear greater.

If the number of screen bypass capacitors were increased to two, the RF current distribution would improve. If eight bypass capacitors are used, see Figure 29, the RF current is evenly distributed throughout the screen assembly, less skin effect losses and lower stray inductance would result.

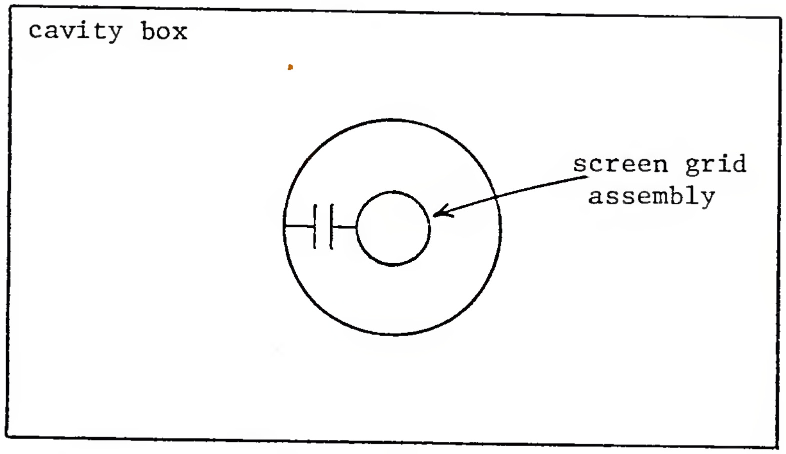


FIGURE 28 - If one screen bypass capcitor is used, an uneven distribution of RF current will result.

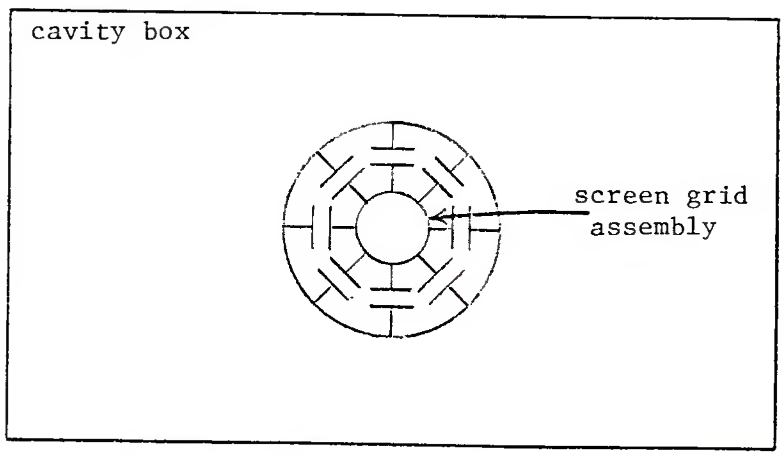
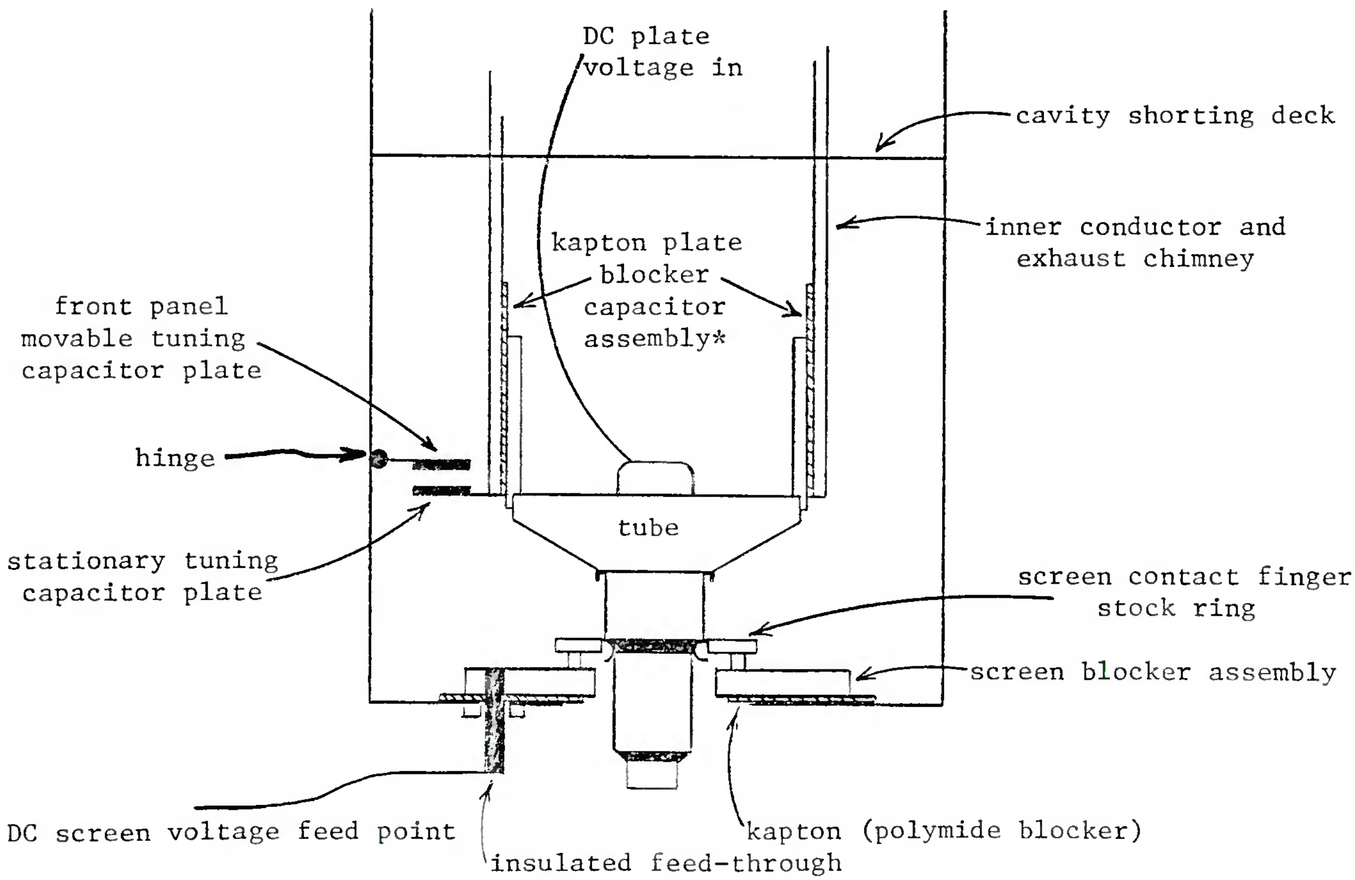


FIGURE 29 - Eight evenly spaced bypass capacitors cause the RF circulating current to divide evenly around the screen assembly.

THE F.M. 25 K QUARTER WAVELENGTH P.A. CAVITY

The quarter wavelength cavity is much simpler than the half wavelength cavity just discussed. It has one coarse tune and one fine tune control. Since the quarter wavelength cavity is shorted at the far end, a plate blocker capacitor must be used to isolate the D.C. plate voltage from ground.



*parts of plate blocker
1. inner tube
2. polymide film(kapton) 0.005" X 8" X 11ft 5 wraps
3. outer anode blocker shell

FIGURE 30 - The FM 25K Quarter Wavelength Cavity

Figure 30 shows a drawing of the quarter wavelength F.M. cavity. The plate of the tube connects directly to the inner half of the exhaust chimney (the inner tube of the plate blocker). The other part of the chimney (the outer anode blocker shell) is connected to the top of the cavity. The D.C. plate voltage is present on the inner tube of the chimney and is isolated from the grounded outer shell of the chimney by the plate blocker capacitor. The plate blocker is formed by wrapping the outside surface of the inner tube of the chimney with five wraps of eight inch wide 0.005 inch thick polymide (kapton) film. The screen contact fingerstock ring is mounted on a metal plate (the screen blocker assembly) which is isolated from the grounded cavity deck by a kapton (polymide film) blocker. The D.C. screen voltage is fed from underneath the cavity deck through an insulated feed through arrangement with one of the corner mounting screws.

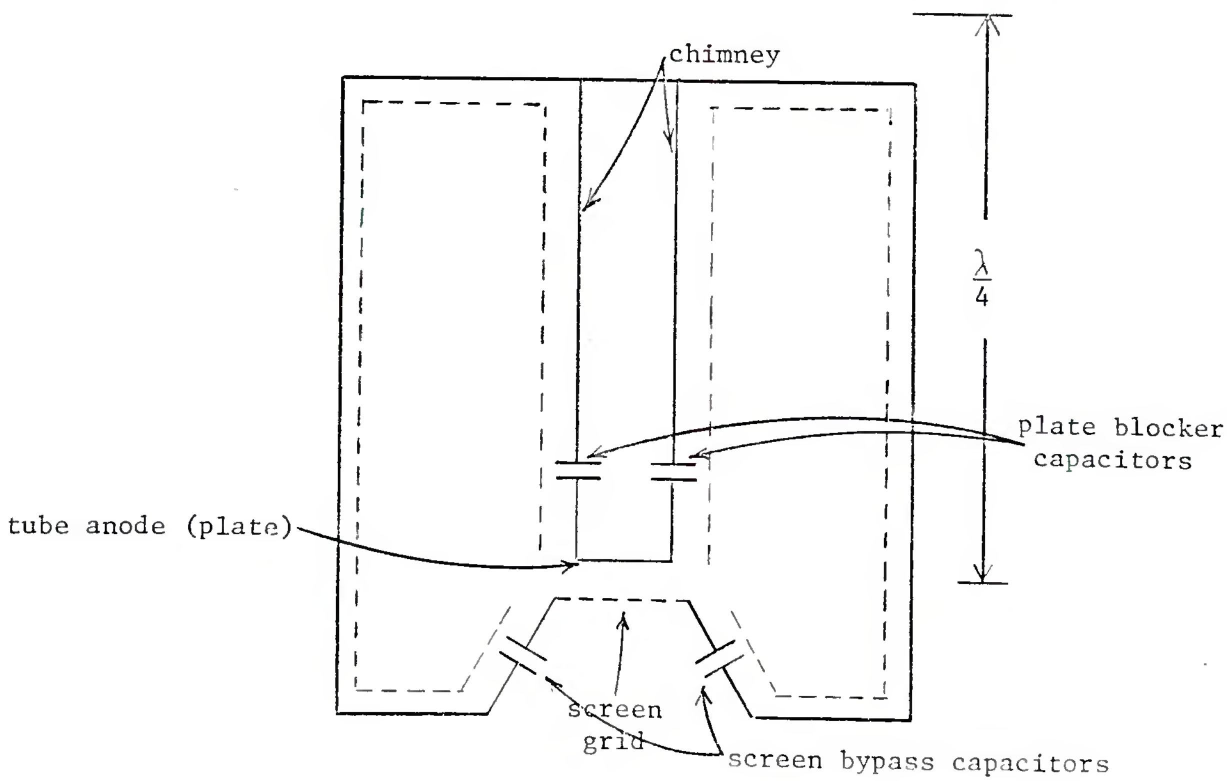


FIGURE 31 - The path for RF circulating currents in the quarter wavelength cavity.

The cavity is slightly shorter than a quarter wavelength. This makes the load inductive and it resonates the tube's output capacity. Thus, the physically foreshortened shorted transmission line is resonated and electrically lengthened to one quarter wavelength.

The RF circulating current flows from the plate, through the plate blocker capacity, and along the inside surface of the cavity (skin effect). It flows up the chimney (the inner conductor), across the top of the cavity, down the inside surface of the cavity box (the outer conductor), across the cavity deck, through the screen blocker, over the screen blocker plate, over the screen contact fingerstock, and into and up the screen grid. (See Figure 31)

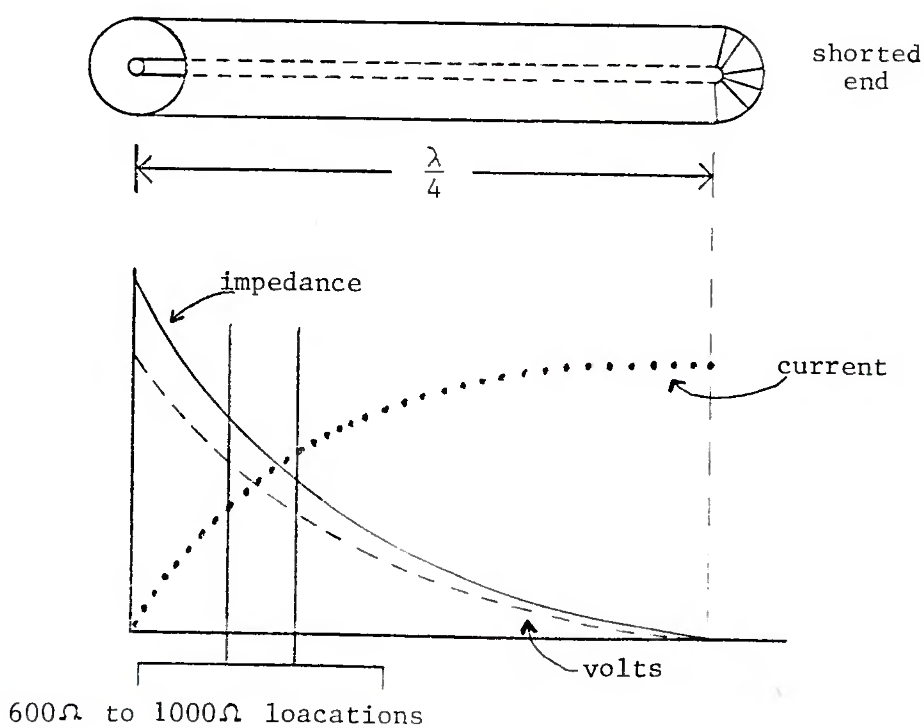


FIGURE 32 - Graph of RF current (.....), RF voltage (----) and RF impedance (———) for a quarter wavelength shorted transmission line. Notice that at the feed point RF current is zero, the RF voltage is maximum, and the RF impedance is infinite.

A graph of RF current, voltage, and impedance for a shorted, quarter wavelength coaxial transmission line shows infinte impedance, zero RF current, and maximum RF voltage at the feed point. This would not be suitable for a tube's plate impedance as the mismatch would cause arcing and poor efficiency. A point on the graph slightly less than $\frac{\lambda}{4}$ is marked. This length yields an impedance of 600 to 800 ohms and would be ideal for the plate. (See Figure 32)

The output capacity of the tube shunts the transmission line that forms the cavity and electrically lengthens it. It is now necessary to physically foreshorten the shorted coaxial transmission line (the cavity) to slightly less than $\frac{\lambda}{4}$. This shorter length is the required length from Figure 32 that will present the required plate impedance.

Figure 33 shows a graph of the RF current, voltage, and impedance presented to the plate of the tube as a result of the physically foreshortened line. This plate impedance now appears to be closer to the ideal 600 to 800 ohms required by the tube's anode.

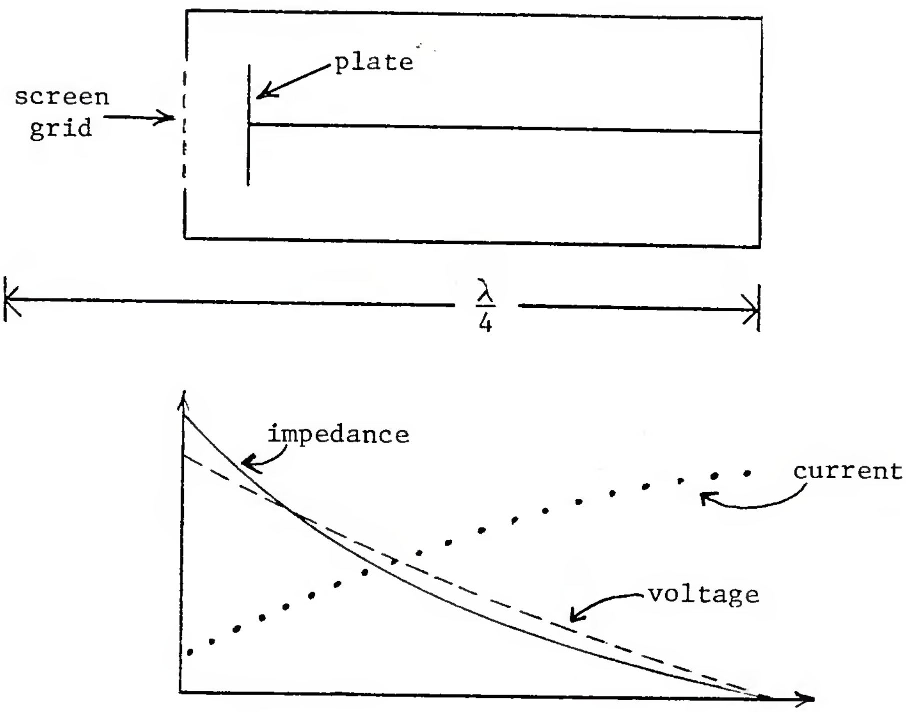


FIGURE 33 - Graph of RF current (......), RF voltage (------) and impedance (———) produced by the physically fore-shortened coaxial transmission line cavity.

COARSE TUNING

The cavity coarse tuning is accomplished by adjusting the cavity length. The top of the cavity (the cavity shorting deck) is fastened by screws and can be raised or lowered to set the length of the cavity for the operating frequency.

FINE TUNING (PLATE TUNE)

The cavity fine tuning is accomplished by the variable capacity that is built into the cavity. One plate of this capacity (the stationary plate) fastens to the inner conductor just above the plate blocker. The front panel movable tuning plate is fastened to the cavity box (outer conductor) and is linked to the plate tuning control. This capacity shunts the inner conductor to the outer conductor and can vary the electrical length and the resonant frequency of the cavity.

THE SCREEN BLOCKER ASSEMBLY

The screen blocker assembly (bypass capacitor) is formed by a metal plate, the deck of the cavity, and a kapton (polymide film) insulating sheet. The RF circulating currents that enter and leave the screen grid follow the surface of the plate, and pass through the kapton blocker to the cavity tube socket deck at the edge of the plate.

THE CAVITY ACCESS DOOR

The cavity access door is part of the outer conductor of the coaxial transmission line. Large values of RF circulating current flow along the inner surface of the door, so it must be fastened securely to prevent arcing.

INDUCTIVE OUTPUT COUPLING

The output coupling circuit is the same for the quarter wavelength and half wavelength cavities just discussed. Both are inductively coupled to the output. In both cavities, the coupling is on the side opposite the cavity access door. The inductive pickup for the half wavelength cavity is a short length of transmission line inner conductor that is terminated by the loading capacitor (See Figure 27). For the quarter wavelength cavity, the inductive pickup loop is a half loop of flat copper bar stock that terminates in the loading capacitor at one end and feeds the output transmission line inner conductor at the other end. In both cavities, the inductive pickup is positioned at a maximum current point in the cavity. They are coupled lightly so that changes in the loading will have minimum effects on the plate tuning.

Adjustment of the loading capacitor matches the 50 ohm transmission line impedance to the impedance of the cavity. Heavy loading, clockwise rotation of the loading control (minimum capacity) lowers the plate impedance presented to the tube by the cavity. Light loading reflects a much higher load impedance to the amplifier's plate.

THE SECOND HARMONIC TRAP

Both cavities have the same type of second harmonic trap in their output transmission line (See Figure 34). The trap is connected to the output transmission line by a tee. It is $\frac{\lambda}{2}$ at the second harmonic frequency and the far end is shorted. The short is repeated at the tee and effectively shorts the cavities output transmission line at the second harmonic fequencies. Any energy at this frequency leaves the cavity, travels down the transmission line to the short, and is reflected back into the cavity and cancels the second harmonic energy present at the "T" due to the 180^{o} phase reversal incurred in the reflection at the end of the filter. It does not get to the antenna.

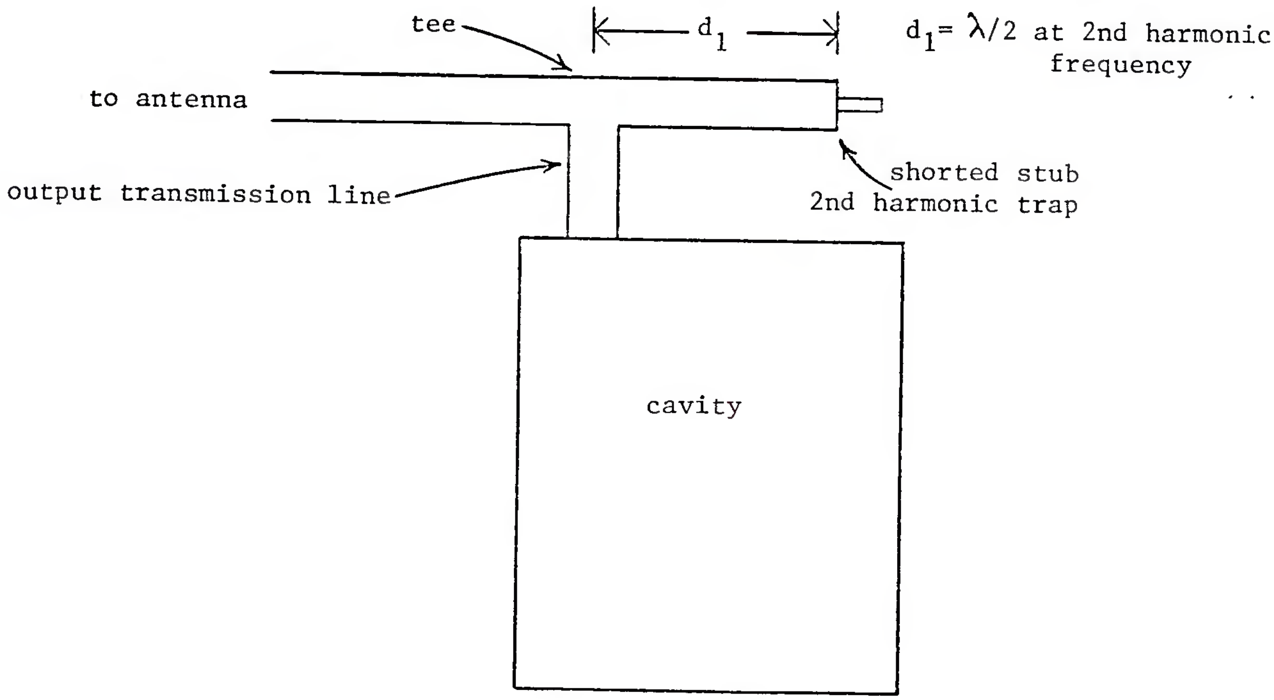
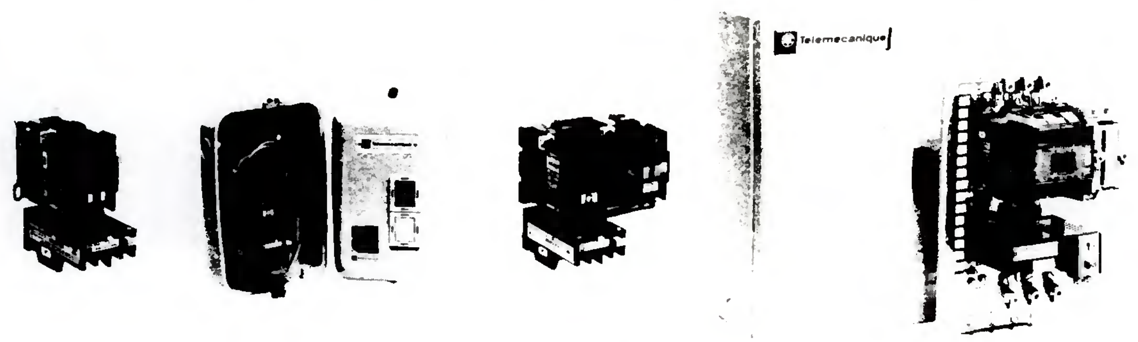


FIGURE 34 - The Second Harmonic Trap.

At the fundamental frequency of the amplifier, the trap is $\frac{\lambda}{4}$ long. The short at the end reflects as an open one-quarter wavelength away at the tee and does not interfere with the fundamental frequency energy traveling down the transmission line to the antenna.



LC1-D123 LE1-D2534 LC2-D129 ND1-FC500

Type	Description	References	Page
Full voltage non-reversing	These magnetic starters provide full voltage starting of three phase squirrel cage motors and protects against overload, and single phase conditions. It consists of non-reversing contactor (LC1, CN2), plus overload relay (LR1, RA1). All starters include a NO holding circuit contact with the possibility of attaching the additional auxiliary contacts listed.	LC1-D ND1 LE1-D	3/4 3/5
Full voltage reversing	These magnetic starters provide reversing control and motor protection for three phase squirrel cage motors. They consist of the standard reversing contactors (LC2, NC4), plus overload relays (LR1, RA1). All devices countain a positive action mechanical interlock plus one NC contact for electrical interlocking. Horizontal configuration is standard. Vertical configuration is available upon request.	LC2 ND2	3/6

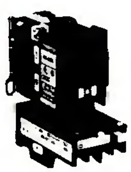
MOTOR HORSE POWER																					
	1/3	1/2	3/4	1	1 ½	2	3	5	7 ½	10	15	20	25	30	40	50	60	75	100	125	150
Single Phase 115 V	D09	D12	D16		D25		D40														
230 V	D09				D12		D16	D40													
Three Phase 200 V	D09						D12	D16	D40				GC								
230 V	D09						D12	D16	D25	D40			FC	GC							
460 V	D09								D12	D16	D25	D40				FC		GC			
575 V	D09									D16		D40				FC			GC		

Application Data

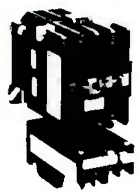
Contactors/Starters

Contactor Starter type	Line Voltage	Maximum HP rating* one phase	Maximum HP rating* three phase	Breaking Capacity (Amps at 460 V)	Nominal Motor current (Amps) †	Continuous rating (Amps) ★	Coil Consumption 60 Hz (VA) Inrush	Coil Consumption 60 Hz (VA) Sealed
D09	115	1/3	—	175	9	24	80	8
	230	1	—					
	200	—	2					
	230	—	2					
	460	—	5					
	575	—	7 ½					
D12	115	1/2	—	175	12	24	80	8
	230	2	—					
	200	—	3					
	230	—	3					
	460	—	7 ½					
	575	—	7 ½					
D16	115	1	—	450	16	32	110	10
	230	3	—					
	200	—	5					
	230	—	5					
	460	—	10					
	575	—	15					
D25	115	2	—	450	25	32	110	10
	230	3	—					
	200	—	5					
	230	—	7 ½					
	460	—	15					
	575	—	15					
D40	115	3	—	1000	40	80	250	25
	230	7 ½	—					
	200	—	10					
	230	—	15					
	460	—	30					
	575	—	40					
[redacted]	115	5	—	1000	63	80	250	25
	230	10	—					
	200	—	20					
	230	—	20					
	460	—	40					
	575	—	40					
FC	200	—	20	2000	80	110	455	45
	230	—	25					
	460	—	60					
	575	—	75					
GC	200	—	30	2600	105	160	600	58
	230	—	40					
	460	—	75					
	575	—	100					
[redacted]	210	—	50	3200	160	210	996	75
	230	—	60					
	460	—	125					
	575	—	150					

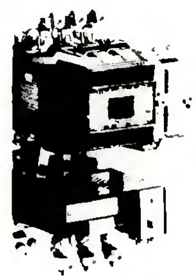
* -HP values are UL listed and CSA approved.
 -Those HP values are valid for up to 5% of the number of operations in inching or plugging service.
 -For jogging or inching service exceeding 5% of total operation, derate one motor size.
† -Maximum motor nameplate current.
★ -Maximum current applied over 8 hour period, without undue temperature rise.



LC1-D123



LC1-D253

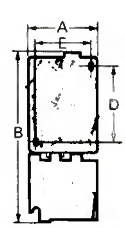


ND1-FC

Starter Type	Maximum Horse Power rating three Phase				Motor load one Phase		Open style type O	
	200 V	230 V	460 V	575 V	115 V	230 V	Catalog No.	$ Price
D09	2	2	5	7 1/2	1/3	1	**LC1-D09** Plus **LR1-D...***	52.00
D12	3	3	7 1/2	7 1/2	1/2	2	**LC1-D12** Plus **LR1-D...***	62.00
D16	5	5	10	15	1	3	**LC1-D16** Plus **LR1-D...***	70.00
D25	5	7 1/2	15	15	2	3	**LC1-D25** Plus **LR1-D...***	76.00
D40	10	15	30	40	3	7 1/2	**LC1-D40** Plus **LR1-D...***	116.00
D63	20	20	40	40	5	10	**LC1-D63** Plus **LR1-D...***	150.00
FC	20	25	60	75	—	—	**ND1-FC100** Plus **RA1...***	206.00
GC	30	40	75	100	—	—	**ND1-GC100** Plus **RA1...***	238.00
HC	50	60	125	150	—	—	**ND1-HC100** Plus **RA1...***	534.00

—D09-D25 starters include 3 poles plus 1 NO auxiliary contact.
—D40-D63-FC-GC-HC includes 1 NO and 1 NC auxiliary contact.
* Includes 3 phase ambient compensated overload protection. Specify motor nameplate current or select overload relay from overload section of this catalog.
For selection of additional auxiliary contact blocks refer to renewal parts and accessories pages at the end of this section.
For complete starter contactor data see front of this section.

APPROXIMATE DIMENSIONS



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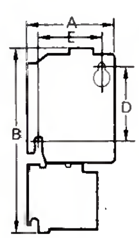

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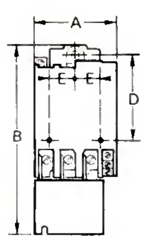

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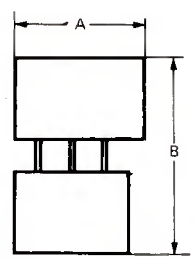

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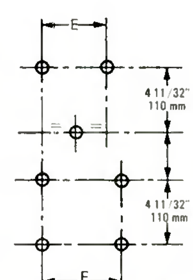


	LC1-D09/D12		LC1-D16/D25		LC1-D40/D63		ND1-FC100		ND1-GC100		ND1-HC100	
A	1 3/4"	44 mm	2 7/32"	56 mm	3"	76 mm	5 5/16"	135 mm	6 9/16"	156 mm	7 7/8"	200 mm
B	4 7/32"	107 mm	4 17/32"	115 mm	6 9/16"	166 mm	9 31/32"	235 mm	10 1/4"	261 mm	11 7/16"	290 mm
C	4 5/32"	105 mm	4 17/32"	115 mm	5"	127 mm	6 1/32"	153 mm	6 1/32"	153 mm	6 1/2"	165 mm
D	2 5/32"	55 mm	2 5/32"	55 mm	4 1/8"	105 mm	23/32"	18.5 mm	23/32"	18.5 mm	1 7/16"	37 mm
E	1 3/8"	35 mm	1 25/32"	45 mm	25/32"	20 mm	2 7/32"	56 mm	2 17/32"	64 mm	3 5/32"	80 mm
F							2 17/32"	64 mm	2 17/32"	64 mm	3 5/32"	80 mm

HOW TO ORDER

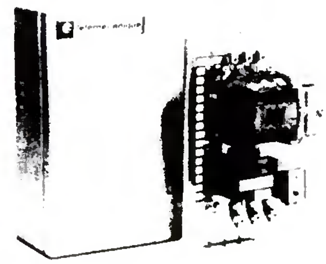
Give: 1. Catalog number of starter.
2. Voltage, phase and frequency of line and coil.
3. Catalog number of overload relay (or give details of load).
4. Quantity and catalog number of additional auxiliary contact blocks and/or accessories (if any) from rear of this section.

[illegible] voltage LE1 ND1

[illegible] enclosed

LE1-D1234

LE1-D4034



ND1-FC500

General Purpose enclosure type 1		Industrial dust tight enclosure type 5 12	
Catalog No.	$ Price	Catalog No.	$ Price
use LE1-D1234		use LE1-D1235	
LE1-D1234*	66.00	LE1-D1235*	76.00
use LE1-D2534		use LE1-D2535	
LE1-D2534*	80.00	LE1-D2535*	104.00
LE1-D4034*	120.00	LE1-D4035*	144.00
use ND1-FC400		use ND1-FC500	
ND1-FC400*	226.00	ND1-FC500*	270.00
ND1-GC400*	278.00	ND1-GC500*	330.00
ND1-HC400*	618.00	ND1-HC500*	790.00

* refer to foot notes under chart on page 3 4.

AUXILIARY CONTACT BLOCKS ELECTRICAL CHARACTERISTICS

Wiring must be same polarity				
Voltage	120 V	240 V	480 V	600 V
A.C. 60 Hz Make	60 A	30 A	15 A	12 A
P.F. 0.35 Break	6 A	3 A	1.5 A	1.2 A
D.C.	1.1 A	.55 A	.25 A	.20 A
10 A Nominal thermal current 600 V AC/DC				

AUX. CONTACT BLOCKS FIELD INSTALLED

D09-D63 type: 1 two pole block max.

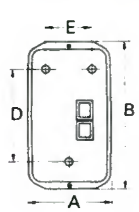
1 NO - 1 NC	**LA1-D11**
2 NO	**LA1-D20**

FC-HC Type: 2 aux. contact blocks max.

1 NO - 1 NC	**ZC1-GP5**
2 NO	**ZC1-GP6**

Standard coil voltages
24, 120, 240, 480, 600 volts 60 Hz
Add $ 5.00 for other voltages.

APPROXIMATE DIMENSIONS



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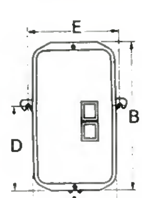

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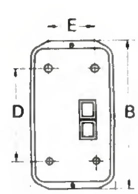

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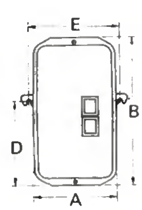

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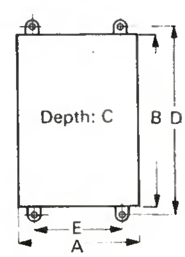


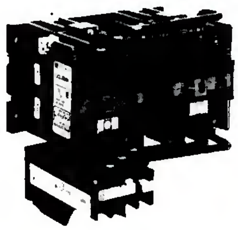
	LED12/D25 Type 1		LED12/D25 Type 5/12		LE1-D40 Type 1		LE1-D40 Type 5/12		ND1-FC400/500		ND1-GC400/500		ND1-HC400/500	
A	6 9/32"	160 mm	6 9/32"	160 mm	7 7/64"	181 mm	7 7/64"	181 mm	9 13/16"	250 mm	9 13/16"	250 mm	11 13/16"	300 mm
B	9 29/32"	252 mm	9 29/32"	252 mm	12 17/64"	312 mm	12 17/64"	312 mm	15 3/4"	400 mm	15 3/4"	400 mm	19 11/16"	500 mm
C	5 13/64"	132 mm	5 13/64"	132 mm	6 1/16"	154 mm	6 1/16"	154 mm	7 7/8"	200 mm	7 7/8"	200 mm	7 7/8"	200 mm
D	5 45/64"	145 mm	5 15/32"	139 mm	7 11/16"	195 mm	6 3/4"	172 mm	16 3/4"	425 mm	16 3/4"	425 mm	20 5/8"	525 mm
E	3 11/32"	85 mm	6 5/8"	168 mm	4 5/32"	105 mm	7 17/32"	192 mm	5 7/8"	150 mm	5 7/8"	150 mm	7 7/8"	200 mm

HOW TO ORDER

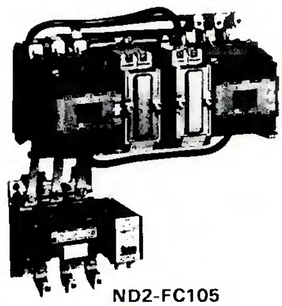
Give:
1. Catalog number of starter.
2. Voltage, phase and frequency of line and coil.
3. Catalog number of overload relay (or give details of load).
4. Quantity and catalog number of additional auxiliary contact blocks and/or accessories (if any) from rear of this section.

[illegible] full voltage [illegible] starters

[illegible] open



LC2-D259

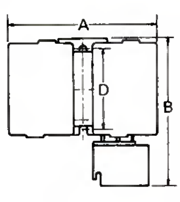


ND2-FC105

Starter type	Maximum Horse Power rating three Phase				Motor load one Phase		Open style type O	
	200 V	230 V	460 V	575 V	115 V	230 V	Catalog No.	$ Price
D09	2	2	5	7 ½	⅓	1	**LC2-D099** Plus **LR1-D...***	106.00
D12	3	3	7 ½	7 ½	½	2	**LC2-D129** Plus **LR1-D...***	138.00
D16	5	5	10	15	1	3	**LC2-D169** Plus **LR1-D...***	151.00
D25	5	7 ½	15	15	2	3	**LC2-D259** Plus **LR1-D...***	162.00
D40	10	15	30	40	3	7 ½	**LC2-D403** Plus **LR1-D...***	256.00
D63	20	20	40	40	5	10	**LC2-D633** Plus **LR1-D...***	3[illegible]6.00
FC	20	25	60	75	–	–	**ND2-FC105** Plus **RA1...***	450.00
GC	30	40	75	100	–	–	**ND2-GC105** Plus **RA1...***	556.00
HC	50	60	125	150	–	–	**ND2-HC105** Plus **RA1...***	1346.00

–D09-D25 reversing starters include two mechanically interlocked contactors each wich 3 poles plus 1 NC auxiliary contact.
–D40-D63-FC-GC-HC includes 1 NO and 1 NC auxiliary contact.
* Includes 3 phase ambient compensated overload protection. Specify motor nameplate current or select overload relay from overload section of this catalog.
–For selection of additional auxiliary contact blocks refer to renewal parts and accessories pages at the end of this section.

APPROXIMATE DIMENSIONS



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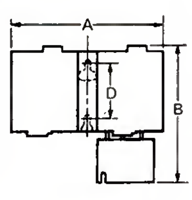

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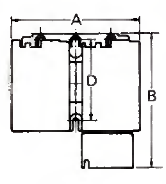

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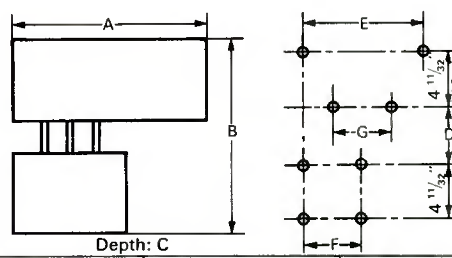


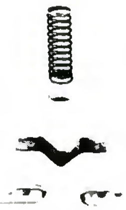
Depth: C

	D09/D12		D16/D25		D40/D63		ND2-FC105		ND2-GC105		ND2-HC105	
A	4 3/64"	103 mm	5"	127 mm	6 ½"	165 mm	11 11/32"	288 mm	13"	330 mm	16 11/32"	615 mm
B	4 7/32"	107 mm	4 17/32"	115 mm	6 9/16"	166 mm	11 5/32"	284 mm	11 15/32"	292 mm	12 11/32"	313 mm
C	3 19/32"	98 mm	4 ¼"	108 mm	5"	127 mm	6 1/32"	153 mm	6 1/32"	153 mm	6 ½"	165 mm
D	2"	50 mm	2"	50 mm	4 ⅛"	105 mm	1 31/32"	50 mm	1 31/32"	50 mm	2 11/32"	60 mm
E							8 15/16"	227 mm	10 13/64"	259 mm	12 ⅞"	327 mm
F							2 17/32"	64 mm	2 17/32"	64 mm	2 5/32"	80 mm
G							6 47/64"	171 mm	7 11/16"	195 mm	9 47/64"	247 mm

HOW TO ORDER

Give:
1. Catalog number of starter.
2. Voltage, phase and frequency of line and coil.
3. Catalog number of overload relay (or give details of load).
4. Quantity and catalog number of additional auxiliary contact blocks and/or accessories (if any) from rear of this section.

Renewal parts and accessories

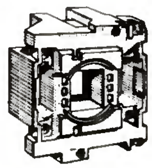


CN2-FC803

WB3-FC

WB3-HC

LX1-D09
D16



LX6-D40

WB3-GC

Coils Combine coil prefix with 3 digit suffix according to coil voltage. Example: need 480 V 60 Hz coil, catalog number is LX1-D09415. The suffix is also the voltage value for 50 Hz coils. Example: need 380 V 50 Hz coil, catalog number is LX1-D09380. Other coil voltages available at additional.

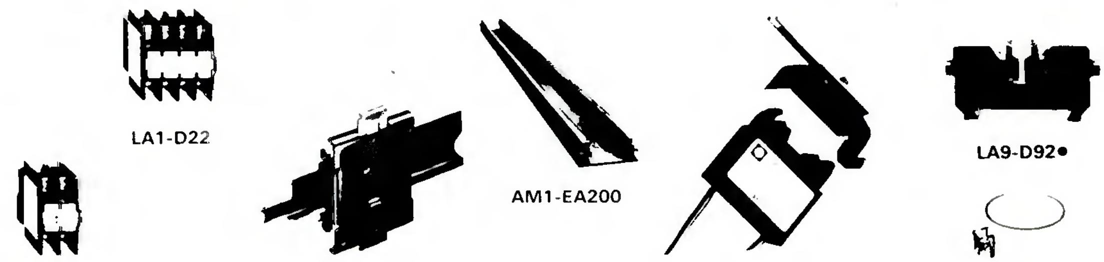
Device Type	Coil Prefix	AC Voltage							List Price
		24/60 Hz	120/60 Hz	208/60 Hz	240/60 Hz	440/60 Hz	480/60 Hz	600/60 Hz	
CA2-D D09 D12	LX1-D09	020	110	200	220	380	415	550	$ 10
D16 D25	LX1-D16	021	110	200	200	380	415	550	$ 14
D40 D63	LX6-D40	020	100	175	185	380	415	500	$ 16
FC	WB3-FC	020	100	173	200	366	400	500	$ 18
GC	WB3-GC	020	100	173	200	366	400	500	$ 21
HC	WB3-HC	020	100	173	200	366	400	500	$ 36

CONTACT KITS

Contactor Type	Description	Catalog Number	List Price
FC	Set of three power poles	CN2-FC803	$ 36
GC	Set of three power poles	CN2-GC803	$ 60
HC	Set of three power poles	CN2-HC803	$ 120

HOW TO ORDER

For coils give coil prefix with three digit voltage suffix (see examples above).
For contact kits give catalog number.
For special coils identify contactor or relay type, and specify voltage (frequency if applicable).



LA1-D22 LA1-D11 AX2-DL01 AM1-EA200 LA9-D09980 LA9-D92● LA9-D901

AUXILIARY CONTACT BLOCKS

Accessory	For use with	Description	Reference No.	List Price
Intantaneous Contact blocks	CA2-D, D09, D12, D16, D25, D40, D63 (1 block max.)	1 NO - 1 NC	LA1-D11	$ 8
		2 NO	LA1-D20	8
		2 NO - 2 NC	LA1-D22	16
		4 NO	LA1-D40	16
		4 NC	LA1-D04	16
		1 NO - 3 NC	LA1-D13	16
		1 NO + 1 NC and 1 NO + 1 NC overlapping	LA1-D1111	16
		1 NO or 1 NC convertible (D16, D25, D40, D63 only)	LA1-D10	5
	FC, GC, HC (2 blocks max.)	1 NO - 1 NC	ZC1-GP5	10
		2 NO	ZC1-GP6	10

TIMERS

On Delay	CA2-D, D09, D12 D16, D25, D40, D63	1 NO+1 NC timed cont. Block 0.1 to 30 sec.	LA2-D22	48.00
		10 to 180 sec.	LA2-D24	48.00
Off Delay	CA2-D, D09, D12 D16, D25, D40, D63	1 NO+1 NC timed cont. Block 0.1 to 30 sec.	LA3-D22	48.00
		10 to 180 sec.	LA3-D24	48.00

MISCELLANEOUS

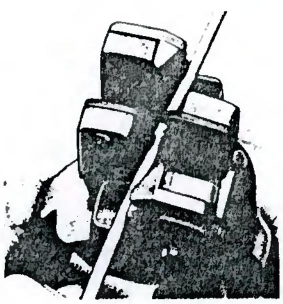
Clip-on Baseplate	Reversing D09, D12	For track mounting	AX2-DL01	2
	Reversing D16, D25	For track mounting	AX2-DL02	2
Mounting Track	CA2-D, D09, D12, D16, D25	Aluminium (2 meters)	AM1-EA200	12
Timer Seal	LA2-D, LA3-D	Clear cover	LA9-D901	2
Transient Suppressor (250 VAC maximum)	CA2-D, D09, D12, D16, D25, D40, D63	Front mounted	LA9-D09980	8
Suppressor Mtg. Support	LA9-D09980	For track, panel or separate mounting	LA9-D09981	2
Pilot light	open style only CA2-D, D09, D12, D16, D25, D40, D63	110 volts	LA9-D924	12
		220 volts	LA9-D925	12

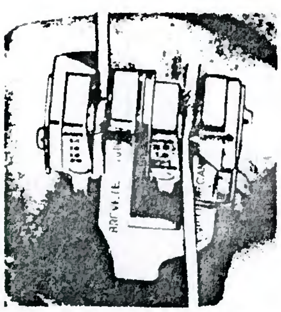
AUXILIARY CONTACT BLOCKS ELECTRICAL CHARACTERISTICS

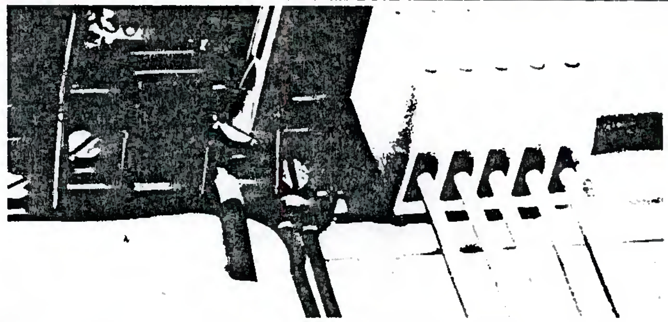
Catalog No.	Device Used On	Voltage		120	240	480	600
LA-...D	Series D contactors starters relays	AC 60 Hz .35 P.F.	Make	60 A	30 A	15 A	12 A
			Break	6 A	3 A	1.5 A	1.2 A
ZC1-GP5 ZC1-GP6	Type FC, GC, HC contactors starters	D.C.		1.1 A	.55 A	.25 A	.2 A
		10 Amp Nominal Continuous Current					

HOW TO ORDER

Give complete catalog number.





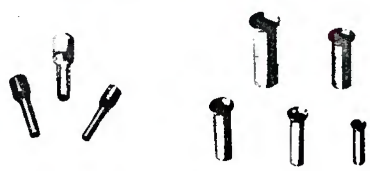


GENERAL

Cable ends are a tubular device for control, pressure type terminals that offer better mechanical and electrical contact between the wire or cable and the terminals. They are self-crimping and secures the wire without soldering or special tools. Gives the user of your equipment the right image of your sence of quality and esthetics.

ELECTRICAL

- Cable ends provide excellent contact to the terminals because it uses the entire cross-sectional area of the cable (unlike bare wire).
- No tinning is required to prevent strands of wire from shorting across to other terminals.
- Increased insulation.



MECHANICAL

Protects cable from vibration found in most industrial applications, preventing cable breaking causing unnecessary production downtime.

- Enables maximum tightening without distorting cable.
- Gives less maintenance cost due to overheating of bare wire terminals.
- Keeps wire strands from moving sideways when in use providing safety.
- Eliminates tinning of wire to keep strands together.

WIRE STRIPPERS

Convenient tool for fast, easier wiring. Cuts and strips both ends of cable from size 14 through 20 AWG (2.5 mm² to 0.36 mm²).

- A single operation results in simultaneous cutting of the cable and stripping of both ends.
- The lenght of the wire bared in the operation will fit our DZ5-CE cable end.

INSULATED TYPE (packages of 1000)

Catalog Number	AWG	Color	$ Price
DZ5-CE007	20 and 18	blue	42.00
DZ5-CE010	18*	red	42.00
DZ5-CE015	16	black	46.00
DZ5-CE020	14	yellow	50.00
DZ5-CE025	14*	gray	50.00

NON-INSULATED TYPE (packages of 100)

DZ5-CE040	12	–	7.00
DZ5-CE060	10	–	9.00
DZ5-CE100	8	–	12.00
DZ5-CE161	6	–	16.00
DZ5-CE251	4	–	20.00

WIRE STRIPPER

DZ5-XC	–	–	110.00

* Used on wire with thick insulation.

HOW TO ORDER

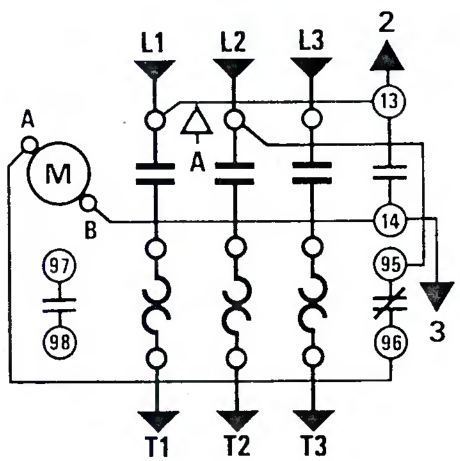
Give complete catalog number.

Typical wiring diagrams for starters

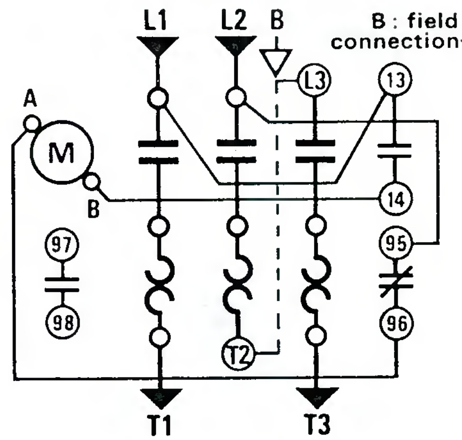
NON REVERSING

WIRING DIAGRAM

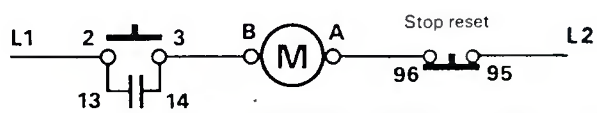
3 phase



Single phase

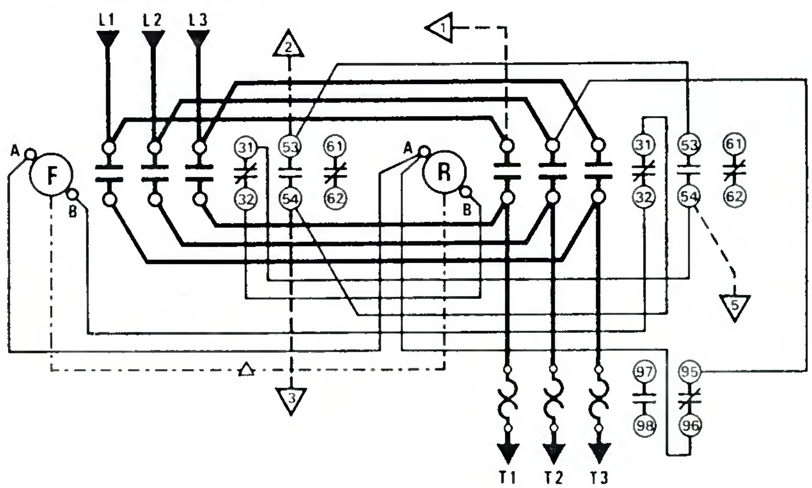


Schematic diagram

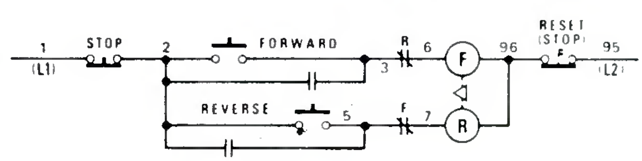


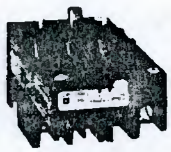
REVERSING

WIRING DIAGRAM

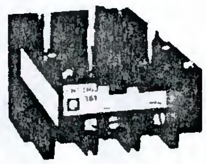


Schematic diagram

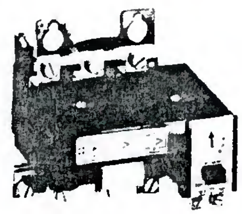




LR1-D09



LR1-D63



RA1-FA to HA

GENERAL

This range of overload relays is thermal ambient compensated. They provide overload protection for polyphase motors:

- Against overloading by a 105 to 120 % nominal current.
- Against phase drop-out.

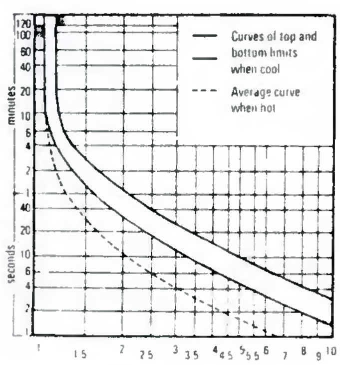
These relays have a tripping mechanism, which is highly sensitive and repetitively accurate, and they can be used with one or three phase AC or DC current.

Each relay carries an independant bimetallic blade for ambient temperature compensation.
Each relay is adjusted by moving a knob or lever to the actual full load current of the motor. They can with ease be directly mounted below a contactor.
The standard NC relay tripping contact remains open until the reset button is fully depressed. One NO alarm contact is also standard on all LR1-D relays. A NO or NC trip signaling contact can be field installed on all the RA1 relays.

Application	Type	Range	Reference	Page
Protection against overload and single phasing -squirrel-cage, slip ring, and shunt motors -any balanced three-phase load	Adjustable triple pole, bimetalic, thermal ambient temperature compensated differential relays	600 V AC 600 V DC 0.1 to 200 A	RA1- LR1	4 2

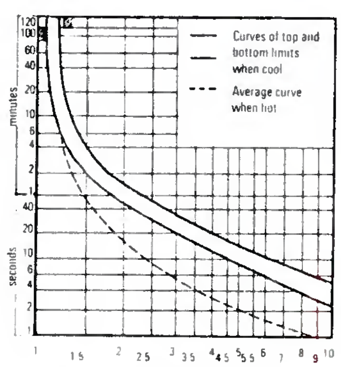
OVERLOAD RELAY TRIPPING CURVES

LR1-D09 to D63



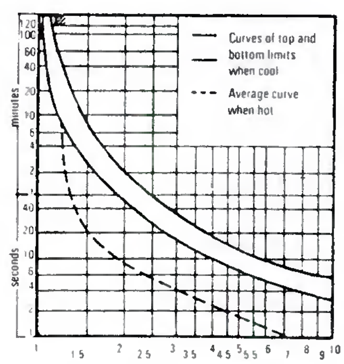
Multiples of full load motor current (setting current)

RA1-FA, GA

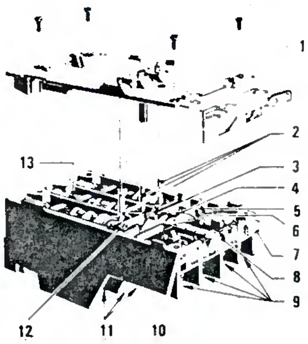


Multiples of full load motor current (setting current)

RA1-HA



Multiples of full load motor current (setting current)



1 Adjustment Seal

2 Input terminals for direct fitting below contactors

3 Tripping Lever

4 Bell Crank Lever

5 Bimetal Compensator

6 Hook

7 Reset Button

8 Adjusting Lever

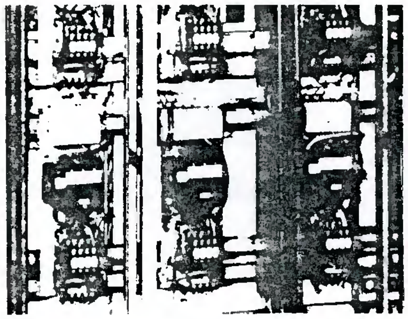
9 NC and NO Contact Terminals

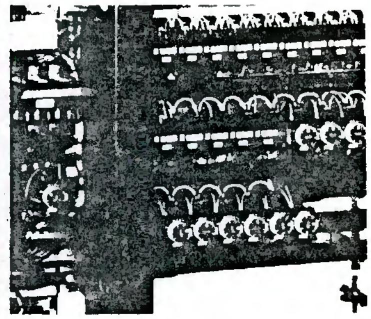
10 NO Contact

11 Output Connecting Terminals

12 Differential Device

13 Thermal Bimetallic Element



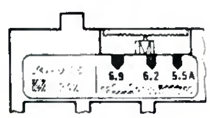


OPERATION

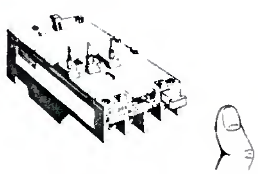
Balanced Overload:
All three bimetals remain parallel and deflect from there normal position when an overcurrent occurs. This moves the differential lever mechanism past the trip point and activates the snap-action contacts.

Phase drop-out:
Absence of current in one phase causes unequal deflection of the bimetallic elements. This difference is amplified by the differential lever displacement actuating the trip mechanism.

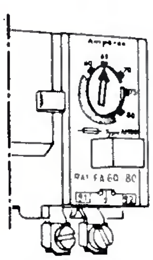
Trip point adjustment:
The trip point is selected by the movement of the adjustment knob or lever to match the motor nameplate current. This adjustment modifies the initial position of the spring loaded trip mechanism (not the contact). Graduations are quite fine and reflect the high sensitivity and accuracy of the overload relay.



Adjustment lever



Reset



Adjustment knob

Reset

ELECTRICAL CHARACTERISTICS

Voltage	120 V	240 V	480 V	600 V
A.C. 60 HZ Make	60 A	30 A	15 A	12 A
P.F. 0.35 Break	6 A	3 A	1.5 A	1.2 A
D.C. current	1.1 A	.55 A	.25 A	.20 A
10 A Nominal thermal current **600 V AC DC**				

Maximum relay voltage	600 V AC DC
Limits to ambient compensation	15 to 160°F −10 to 70°C
Frequency range	Up to 500 HZ

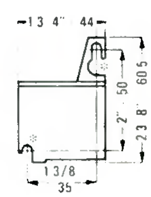
INDEPENDANT MOUNTING

Marking

Assembly with mounting plate Ref: LA7-D0954

Depth: 3. 1 2

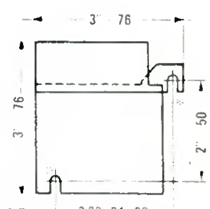
90 m.m



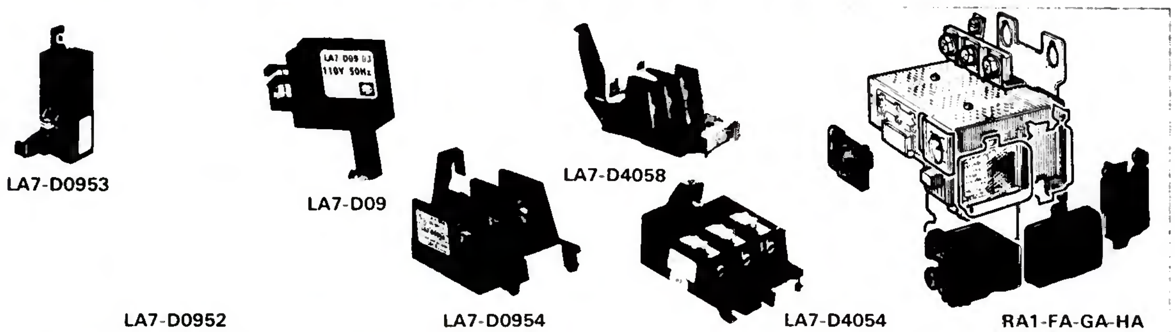
Assembly with mounting plate Ref: LA7-D4054.

Depth: 4. 17 32

115 m.m



: For U.N.F. 8 screws.



Recommended range (amperes)	Catalog No.	$ Price
MANUAL RESET LR1-D		
0.1 to 0.15 A	LR1-D09301	16.00
0.16 to 0.24 A	LR1-D09302	16.00
0.25 to 0.39 A	LR1-D09303	16.00
0.4 to 0.62 A	LR1-D09304	16.00
0.63 to 0.99 A	LR1-D09305	16.00
1.0 to 1.5 A	LR1-D09306	16.00
1.6 to 2.4 A	LR1-D09307	16.00
2.5 to 3.9 A	LR1-D09308	16.00
4.0 to 5.4 A	LR1-D09310	16.00
5.5 to 6.9 A	LR1-D09312	16.00
7.0 to 9.9 A	LR1-D09314	16.00
10 to 12.9 A	LR1-D12316	16.00
13 to 17.9 A	LR1-D16321	18.00
18 to 25 A	LR1-D25322	18.00
23 to 29.9 A	LR1-D40353	26.00
30 to 40 A	LR1-D40355	26.00
38 to 47.9 A	LR1-D63357	26.00
48 to 56.9 A	LR1-D63359	26.00
57 to 66 A	LR1-D63361	26.00
RA1-FA - GA - HA (*) types		
1 to 1.5 A	RA1-FA116	26.00
1.6 to 2.4 A	RA1-FA1625	26.00
2.5 to 3.9 A	RA1-FA254	26.00
4 to 5.4 A	RA1-FA46	26.00
5.5 to 6.9 A	RA1-FA558	26.00
7 to 10 A	RA1-FA710	26.00
9 to 10.9 A	RA1-FA912	26.00
11 to 13.9 A	RA1-FA1116	26.00
14 to 20 A	RA1-FA1420	26.00
18 to 22.9 A	RA1-FA1825	26.00
23 to 29.9 A	RA1-FA2332	26.00
30 to 37.9 A	RA1-FA3040	26.00
38 to 47.9 A	RA1-FA3850	26.00
48 to 59.9 A	RA1-FA4863	26.00
60 to 80 A	RA1-FA6080	26.00
75 to 105 A	RA1-GA75105	38.00
95 to 119 A	RA1-HA95125*	54.00
120 to 149 A	RA1-HA120160*	54.00
150 to 200 A	RA1-HA150200*	54.00

Special features LR1-D		Catalog No.	$ Price
Remote reset†	D09 - D25	LA7-D0953	16.00
	D40 - D63	LA7-D4053	16.00
Remote trip†	D09 - D25	LA7-D0903	16.00
	D40 - D63	LA7-D4003	16.00
Separate mounting support	D09 - D25	LA7-D0954	3.00
	D40 - D63	LA7-D4054	6.00
Adaptor to LC1-D40, D63★	D09 - D25	LA7-D4058	2.00
Adjustment Seal	D09 - D25	LA7-D0952	2.00
	D40 - D63	LA7-D4052	2.00

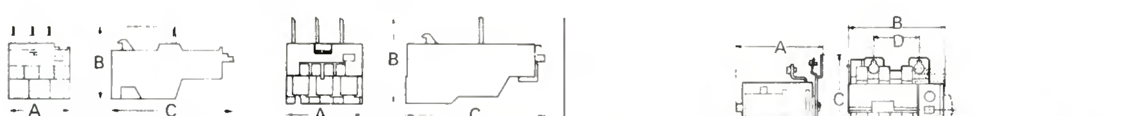
Special features RA1-FA-GA-HA		Catalog No.	$ Price
Trip Signaling	NO	ZC1-RP1	4.00
	NC	ZC1-RP2	4.00
Remote reset†		ER1-FA2	24.00
Remote trip†		ER1-FA1	10.00
Adjustment seal		RA1-FZ01	[illegible]

† When ordering please specify voltage.

NOTE: These devices must not be energized longer than 2.0 seconds

★ To mount LR1-D09 to D25 on LC1/LC2-D40, D63.

* RA1-HA type for AC use only. For DC use consult nearest sales office.



	LR1-D09 to D25		LR1-D40 to D63		RA1-FA-GA		RA1-HA	
A	1 3/4"	44 mm	2 1/2"	63.5 mm	4 13/16"	122 mm	5 41/64"	143 mm
B	2 1/8"	53 mm	2 7/8"	72 mm	5 5/16"	135 mm	6 17/64"	159 mm
C	3 1/2"	90 mm	4 17/32"	115 mm	4 57/64"	124 mm	4 57/64"	124 mm
D					2 17/32"	64 mm	3 5/32"	80 mm

HOW TO ORDER

Give selected relay and attachment complete catalog number.

HARRIS ENGINEERING DEPARTMENT
POWER DISTRIBUTION RECOMMENDATION

Radio and Television transmitters using three-phase power must operate with the line-to-line voltages well balanced. Operation with the incoming line-to-line voltages substantially unbalanced will increase the ripple from the three-phase power supplies, primarily at twice the power line frequency, and thus increase the hum of the transmitter. Unbalanced line voltages result in unbalanced currents in the windings of the three-phase transformers, and in unbalanced currents in the windings of three-phase motors.

Three-phase motors should be run with line voltage balance within 1%; a 3-1/2 percent line voltage unbalanced will produce a temperature rise approximately 25% above normal in the winding carrying the greater of the unbalanced currents, while a 5% unbalance will produce a temperature rise approximately 50% greater than normal.

The regulation of a three-phase open delta transformer bank is much poorer than that of a closed delta bank.[1] The closed delta bank is symmetrical; the open delta is not; so the regulation in each of the three phases differs widely, and the effect of this may be an appreciable line voltage unbalance. The regulation of a closed delta is symmetrical on each phase.

Depending upon the impedances of the two transformers making up the open delta this appreciable line voltage unbalance may be great enough to impair satisfactory operation of the transmitter. HARRIS customers have experienced this with open delta distribution, and when the third transformer was added for closed delta service, the problem disappeared.

Transient overvoltages with open delta distribution can cause transmitter damage, particularly to the silicon rectifiers used in the main HV power supply. This is sometimes troublesome when the open delta transformers are at the end of a long overhead open wire distribution system. Several HARRIS

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1. "Transformer Engineering" - Blume, Boyajian, Camilli, Lennox, Minneci, & Montsinger (John Wiley & Sons). 2nd 1967.

customers, upon following the HARRIS recommendation and adding the third transformer, have found the difficulty gone.

Although the above argument specifically calls out Closed Delta distribution, a WYE distribution also uses three transformers, and is symmetric, avoiding the difficulties arising from the non-symmetrical configuration of the Open Delta distribution.

WYE TYPE POWER DISTRIBUTION

In large segments of the world the power distribution is four-wire WYE. Single phase service is derived between the neutral of the WYE distribution and any one of the three other wires.

Three-phase main power supply transformers for small transmitters - 10 kilowatts or less - in the United States are generally operated from three-phase lines in the 210 to 250 volt range, line to line. HARRIS has adopted the practice of specifying three-phase transformers for transmitters of this class with three separate primaries, each having appropriate taps to accommodate the several nominal voltages in this range. For service in the United States these primaries are connected in Delta.

For service in those parts of the world in which the power distribution is four-wire WYE in the 360 to 415-volt range these three primaries are connected tin WYE, with each primary tapped for the line to neutral voltage. The neutral point of the three primaries of the transformer within the transformer within the transmitter is solidly connected to the power distribution system neutral, to provide a path for zero sequence currents, as well as any harmonic currents which might flow due to the rectification of the secondary voltages.

The line-to-line voltage is equal to the line to neutral voltage multiplied by the square root of three (1.732 approximately), nominally.

Typical system voltages: (Nominal)

LINE TO NEUTRAL (single phase)	LINE TO LINE (three phase)
210 volts	364 volts
220 volts	380 volts
230 volts	400 volts
240 volts	415 volts
250 volts	433 volts

In summary, either a closed delta or WYE distribution system is satisfactory for HARRIS transmitter.