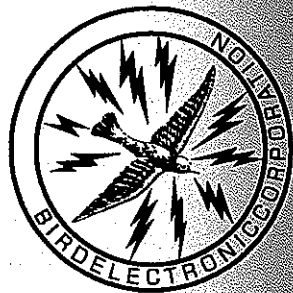


OPERATING INSTRUCTIONS

**THRULINE® WATTMETER
SERIES 4700A**



LIMITED WARRANTY

All products manufactured by Seller are warranted to be free from defects in material and workmanship for a period of one (1) year, unless otherwise specified, from date of shipment and to conform to applicable specifications, drawings, blueprints and/or samples. Seller's sole obligation under these warranties shall be to issue credit, repair or replace any item or part thereof which is proved to be other than as warranted; no allowance shall be made for any labor charges of Buyer for replacement of parts, adjustment or repairs, or any other work, unless such charges are authorized in advance by Seller.

If Seller's products are claimed to be defective in material or workmanship or not to conform to specifications, drawings, blueprints and/or samples, Seller shall, upon prompt notice thereof, either examine the products where they are located or issue shipping instructions for return to Seller (transportation-charges prepaid by Buyer). In the event any of our products are proved to be other than as warranted, transportation costs (cheapest way) to and from Seller's plant, will be borne by Seller and reimbursement or credit will be made for amounts so expended by Buyer. Every such claim for breach of these warranties shall be deemed to be waived by Buyer unless made in writing within ten (10) days from the date of discovery of the defect.

The above warranties shall not extend to any products or parts thereof which have been subjected to any misuse or neglect, damaged by accident, rendered defective by reason of improper installation or by the performance of repairs or alterations outside of our plant, and shall not apply to any goods or parts thereof furnished by Buyer or acquired from others at Buyer's request and/or to Buyer's specifications. In addition, Seller's warranties do not extend to the failure of tubes, transistors, fuses and batteries, or to other equipment and parts manufactured by others except to the extent of the original manufacturer's warranty to Seller.

The obligations under the foregoing warranties are limited to the precise terms thereof. These warranties provide exclusive remedies, expressly in lieu of all other remedies including claims for special or consequential damages. SELLER NEITHER MAKES NOR ASSUMES ANY OTHER WARRANTY WHATSOEVER, WHETHER EXPRESS, STATUTORY, OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS, AND NO PERSON IS AUTHORIZED TO ASSUME FOR SELLER ANY OBLIGATION OR LIABILITY NOT STRICTLY IN ACCORDANCE WITH THE FOREGOING.

MODELS COVERED IN THIS INSTRUCTION BOOK

| | | |
|-------|-------|-----------|
| 4712A | 4715- | 4720A |
| 4712- | 200A | 4723-200A |
| 037A | 4715- | |
| | 300A | |

INSTRUCTION BOOK

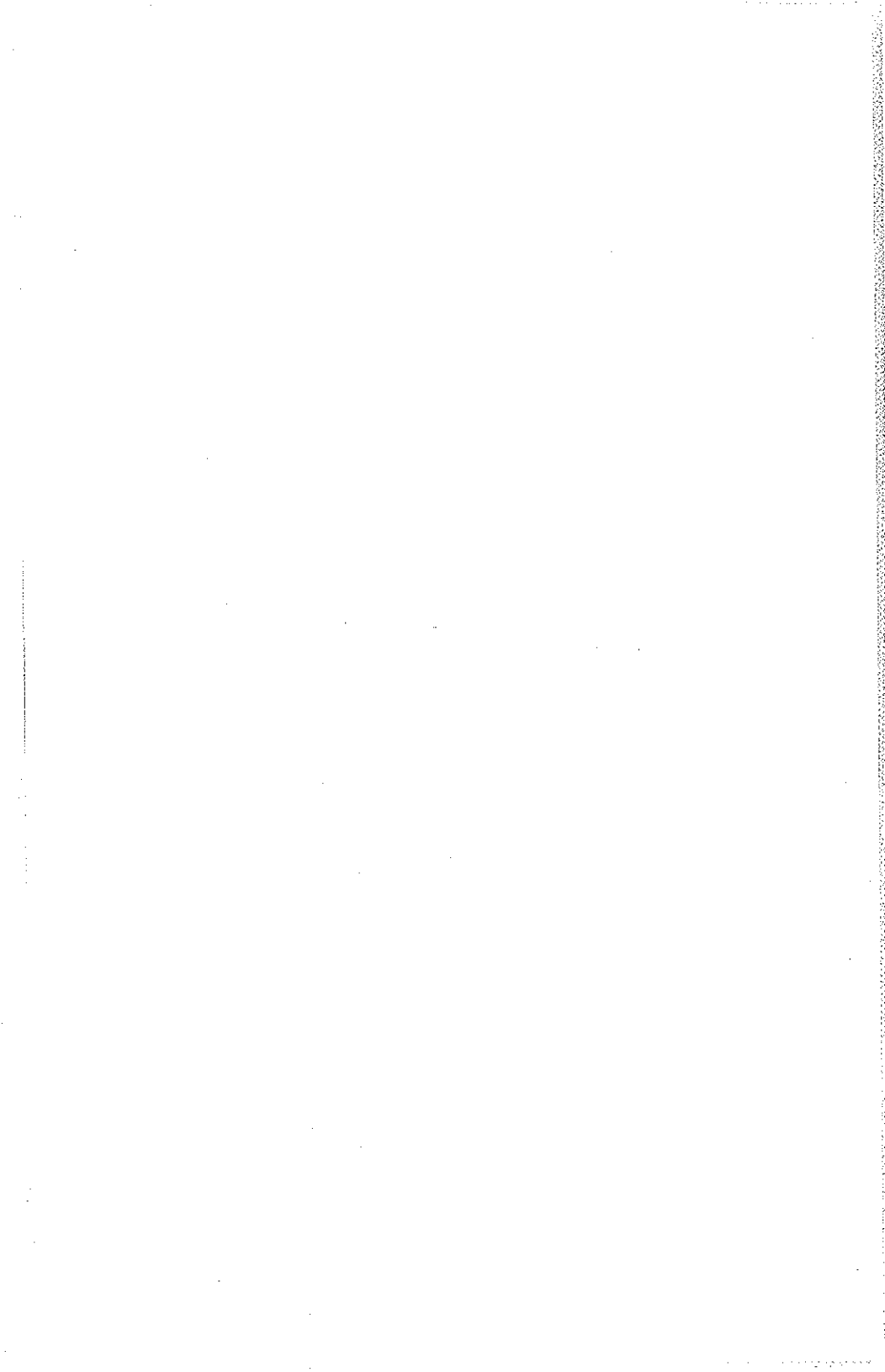
**THRULINE® WATTMETER
SERIES 4700A**

BIRD

Electronic Corporation

30303 Aurora Road, Cleveland, Ohio 44139-2794

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Instruction Book Part Number 920-4700AS



SAFETY PRECAUTIONS

The following are general safety precautions that are not necessarily related to any specific part or procedure and do not necessarily appear elsewhere in this publication.

KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must at all times observe normal safety regulations. Do not attempt to replace parts or disconnect an RF transmission or any other high voltage line while power is applied. When working with high voltage always have someone present who is capable of rendering aid if necessary. Personnel working with or near high voltage should be familiar with modern methods of resuscitation.

DO NOT SERVICE OR ADJUST ALONE

Under no circumstances should any person reach into an enclosure for the purpose of service or adjustment of equipment except in the presence of someone who is capable of rendering aid.

SAFETY EARTH GROUND

An uninterruptible earth safety ground must be supplied from the main power source to test instruments. Grounding one conductor of a two conductor power cable is not sufficient protection. Serious injury or death can occur if this grounding is not properly supplied.

SHOCK HAZARD

Do not attempt to remove an RF transmission line while power is present.

CHEMICAL HAZARD

Dry cleaning solvents used to clean parts may be potentially dangerous to your health. Avoid inhalation of fumes and also prolonged contact with skin.

RESUSCITATION

Personnel working with or near high voltages should be familiar with modern methods of resuscitation.

4700A THRULINE® Wattmeter

SAFETY SYMBOLS

WARNING

Warning: Warning notes call attention to a procedure, which if not correctly performed could result in personal injury.

CAUTION

Caution: Caution notes call attention to a procedure, which if not correctly performed could result in damage to the instrument.

The following warnings appear in the text where there is procedures, that if not carefully followed, could be detrimental to operating and maintenance personnel and are repeated here for emphasis.

WARNING

Never attempt to disconnect the transmission line while RF power is being applied. Leaking RF energy is a potential health hazard.

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that may be harmful to your health, if inhaled.

4700A THRULINE® Wattmeter

The following equipment cautions appear in the text whenever a procedure, if not properly followed, could put the equipment in danger of damage and are repeated here for emphasis.

CAUTION

The wattmeter, the THRULINE® element and the RF line section, collectively referred to as THRULINE® in the remainder of this section, all have matching serial numbers. Do not intermix these parts with parts from other THRULINE® equipment.

CAUTION

Under no circumstances attempt to remove the RF center conductor. It is tightly frozen in place and any attempt to remove it will ruin the assembly.

TABLE OF CONTENTS

| Section | Paragraph | Page |
|------------|---|------|
| | Safety Precautions | i |
| I | INTRODUCTION | |
| | 1.1 Purpose and Function | 1-1 |
| | 1.2 Performance Capabilities and Characteristics | 1-1 |
| | 1.3 Dimensions and Weight | 1-1 |
| | 1.4 Power and Utility Requirements | 1-1 |
| | 1.5 Environmental Requirements | 1-1 |
| | 1.6 Items Furnished | 1-2 |
| | 1.7 Items Required | 1-2 |
| | 1.8 Tools and Test Equipment | 1-2 |
| | 1.9 Unit Specifications | 1-3 |
| II | INSTALLATION | |
| | 2.1 Location | 2-1 |
| | 2.2 Coupling Kits | 2-1 |
| | 2.3 Mounting | 2-1 |
| | 2.4 Meter Placement | 2-2 |
| III | THEORY OF OPERATION | |
| | 3.1 Traveling Wave Viewpoint | 3-1 |
| | 3.2 Coupling Circuit | 3-1 |
| | 3.3 Element Socket | 3-2 |
| | 3.4 Matching | 3-3 |
| | 3.5 Load Power | 3-3 |
| | 3.6 P vs ϕ and its Significance | 3-4 |
| | 3.7 Measurement and Monitoring of Transmitter Power | 3-4 |
| IV | OPERATING INSTRUCTIONS | |
| | 4.1 Use and Function of Controls | 4-1 |
| | 4.2 Initial Adjustments and Control Settings | 4-1 |
| | 4.3 Start-Up | 4-1 |
| | 4.4 Normal Operation | 4-2 |
| | 4.5 Operation Under Abnormal Conditions | 4-2 |
| | 4.6 Shutdown | 4-2 |
| | 4.7 Emergency Shutdown | 4-2 |

TABLE OF CONTENTS [CONT.]

| Section | Paragraph | Page |
|-------------|-----------------------------------|------|
| V | MAINTENANCE | |
| | 5.1 Troubleshooting | 5-1 |
| | 5.2 Cleaning | 5-2 |
| | 5.3 Inspection | 5-3 |
| | 5.4 Preventive Maintenance | 5-3 |
| | 5.5 Line Section Care | 5-3 |
| | 5.6 Disassembly | 5-3 |
| | 5.7 Reassembly | 5-4 |
| | 5.8 Repairs | 5-4 |
| | 5.9 Contact Adjustment | 5-4 |
| VI | PREPARATION FOR RESHIPMENT | |
| | 6.1 Elements | 6-1 |
| | 6.2 Line Section | 6-1 |
| | 6.3 DC Cables | 6-1 |
| | 6.4 Meter | 6-1 |
| VII | STORAGE | |
| | 7.1 General | 7-1 |
| VIII | REPLACEMENT PARTS LIST | |
| | 8.1 Series 4700A | 8-1 |

LIST OF ILLUSTRATIONS

| Figure | Title | Page |
|--------|--|------|
| 1-1 | Outline Drawing of Line Sections | 1-7 |
| 1-2 | Schematic Diagram - Element | 1-8 |

LIST OF TABLES

| Table | Title | Page |
|--------------|-------------------------------|-------------|
| 1-1 | Summary Elements Tables | 1-5 |

SECTION I. INTRODUCTION

1.1. PURPOSE AND FUNCTION

The Series 4700A THRULINE® Wattmeters are directional RF wattmeters that detect and measure power flow in either direction in 1-5/8 inch coaxial transmission lines. They are designed for a 50 ohm characteristic impedance. Therefore, they are useful for load matching in standard coaxial lines. Power levels are indicated on a direct reading meter in accordance with the elements selected by the user.

1.2. PERFORMANCE CAPABILITIES AND CHARACTERISTICS

Elements are available for measuring power levels up to 25 kW (6 kW for Models 4712-037A and 4715-300A) full scale in stated frequency bands from 2 to 1000 MHz (50 to 250 MHz for Models 4712-037A and 4715-300A). Other wattmeter systems of 8 kW for frequencies from 100 to 250 MHz can be formulated on special order. The maximum measurement error is ± 5 percent of the power rating of the element. The insertion VSWR (voltage standing wave ratio) will not exceed 1.05 to 1 over the stated frequency band.

1.3. DIMENSIONS AND WEIGHT

The flanged sections of Models 4712A, 4715-200A, 4712-037A, and 4715-300A are 6-3/4 inch (171.5 mm) from flange face to flange face. The barrel of the line section is 1-5/8 inch (41.3 mm), and the flange fittings are 3-1/2 inch (89 mm). The weight of the single socket line section is 3 lb (1.4 kg) and the double socket is 3-1/4 lb (1.5 kg). The unflanged line sections are 6-3/8 inch (162 mm) to end and the barrel 1-5/8 inch (41.3 mm). The single socket line section weighs 1-1/4 lb (0.6 kg) and the double socket 1-1/2 lb (0.7 kg). The meter and housings are 3-11/64 inch L x 5-9/16 inch W x 6-1/2 inch H (80.6 x 141 x 165 mm) and weigh approximately 3 lb (1.36 kg). Add 2 lb (0.9 kg) for the overall shipping weight.

1.4. POWER AND UTILITY REQUIREMENTS

THRULINE® Wattmeters are passive and self-contained devices; they do not require any utility service or outside power, other than the RF input power, for operation.

1.5. ENVIRONMENTAL REQUIREMENTS

THRULINE® Wattmeters should be used preferably in a dust and vibration-free environment. Measurements should be made at 25°C ± 5 °C (77°F ± 9 °F) for maximum measurement accuracy.

4700A THRULINE® Wattmeter

1.6 ITEMS FURNISHED

Series 4700A THRULINE® Wattmeters consist of a line section, a detector element, a meter in a housing, and connecting cables.

The line section is a short length of matching 1-5/8 inch coaxial transmission line. For Models 4712-000A, 4712-037A, and 4715-300A the line section has flanges that are fixed on one end and swivel type on the other. Models 4720A and 4723-200A are unflanged line sections.

The meter is scaled in 5, 10, and 25 kW ranges for Models 4712A, 4715-200A, 4720A, and 4723-200A. Models 4712-037A and 4715-300A are scaled in 15, 30, and 60 kW ranges. Other wattmeter combinations include scales of 8 and 80 kW ranges.

A standard ten foot (three meter) cable/s is supplied with each wattmeter and is equipped with a dc connector plug on one end and lugs on the other. Alternate lengths are available on request. This instruction book is the only other item supplied.

Wattmeters with two separate element sockets (one for FORWARD and one for REFLECTED power measurement) are equipped with a dual dc input meter case and two shielded cables. A switch mounted on the meter face selects the desired reading.

1.7. ITEMS REQUIRED

The coaxial transmission line must be equipped with 1-5/8 inch flanged or unflanged connectors to match the line section. Additional elements must be ordered for the desired frequency bands and power levels (see pages 1-5 and 1-6).

1.8. TOOLS AND TEST EQUIPMENT

End wrenches or an adjustable wrench for the flange bolts are the only tools required for the Series 4700A Wattmeters.

1.9. UNIT SPECIFICATIONS

SERIES 4700A THRULINE® WATTMETER

| | |
|----------------------------------|--|
| Impedance | 50 ohms nominal |
| Insertion VSWR | 1.05:1.00 maximum |
| Accuracy | ±5% of full scale |
| Dimensions | |
| Flanged Line Section | 6-3/4"L (171 mm) |
| Unflanged Line Section | 6-3/8"L (162 mm) |
| Meter | 3-11/64"L x 5-9/16"W x 6-1/2"H (80.6 x 141 x 165 mm) |
| Weight | |
| Flanged Line Section | Approx. 3 lb (1.36 kg) |
| Unflanged Line Section | Approx. 1.25 lb (0.57 kg) |
| Meter | Approx. 3 lb (1.36 kg) |
| Ambient Temperature | 25°C ±5°C (77°F ±9°F) |
| Finish | |
| Meter Housing | Light navy grey baked enamel (MIL-E-15090) |
| Line Section | Bright silver plate |

| <u>Model Number</u> | <u>Frequency Range MHz</u> | <u>Power Range kW</u> | <u>Scale</u> | <u>Element Table</u> | <u>Connector Type</u> | <u>Sockets</u> |
|-------------------------|------------------------------------|-------------------------------|--------------|--------------------------|---------------------------|----------------|
| 4712A | 2-1000 | 0.25-25 | 5/10/25 | 1-5/8A | 1-5/8" Flg | Single |
| 4715-200A | 2-1000 | 0.25-25 | 5/10/25 | 1-5/8A | 1-5/8" Flg | Double |
| 4720A | 2-1000 | 0.25-25 | 5/10/25 | 1-5/8A | 1-5/8" Unfl | Single |
| 4723-200A | 2-1000 | 0.25-25 | 5/10/25 | 1-5/8A | 1-5/8" Unfl | Double |
| 4712-037A | 50-250 | 0.3-6 | 15/30/60 | 1-5/8B | 1-5/8" Flg | Single |
| 4715-300A | 50-250 | 0.3-6 | 15/30/60 | 1-5/8B | 1-5/8" Flg | Double |

4700A THRULINE® Wattmeter

UNIT SPECIFICATIONS [CONT.]

Note: Actual frequency and power ranges are determined by element used (see Page ix).

NOTE:

- a. Models 4712A and 4720A utilize meter in housing assembly, P/N 6810-309-7, and replacement meter, P/N 2150-230.
 - b. Models 4715-200A and 4723-200A utilize meter in housing assembly, P/N 6810-220, and replacement meter, P/N 2150-230.
 - c. Model 4712-037A utilizes meter in housing assembly, P/N 6810-307, and replacement meter, P/N 2150-259.
 - d. Model 4715-300A utilizes meter in housing assembly, P/N 6810-230, and replacement meter, P/N 2150-259.
 - e. Wattmeter systems using 8 kW elements utilize meter in housing assembly, P/N 6810-265 and replacement meter P/N 2150-268.
-

Table 1-1. Summary Element Tables

Table 1-5/8A - 100 μ amp

| Power Range | Frequency Bands (MHz) | | | | | |
|-------------|-----------------------|--------|--------|---------|---------|----------|
| | 2-30 | 25-60 | 50-125 | 100-250 | 200-500 | 400-1000 |
| 100 W | | | 100B1 | 100C1 | 100D1 | 100E1 |
| 250 W | | 250A1 | 250B1 | 250C1 | 250D1 | 250E1 |
| 500 W | | 500A1 | 500B1 | 500C1 | 500D1 | 500E1 |
| 1000 W | 1000H1 | 1000A1 | 1000B1 | 1000C1 | 1000D1 | 1000E1 |
| 2500 W | 2500H1 | 2500A1 | 2500B1 | 2500C1 | 2500D1 | 2500E1 |
| 5000 W | 5000H1 | 5000A1 | 5000B1 | 5000C1 | 5000D1 | 5000E1 |
| 10 kW | 10KH1 | 10KA1 | 10KB1 | 10KC1 | | |
| 25 kW | 25KH1 | 25KA1 | 25KB1 | | | |

* When ordering, specify catalog number and line section model number.
 Note - Transmission line power rating should not be exceeded.

Table 1-5/8AA - 30 μ amp

| Power Range | Frequency Bands (MHz) | | | | | |
|-------------|-----------------------|---------|---------|---------|---------|----------|
| | 2-30 | 25-60 | 50-125 | 100-250 | 200-500 | 400-1000 |
| 250 W | | 250A12 | 250B12 | 250C12 | 250D12 | 250E12 |
| 500 W | 500H12 | 500A12 | 500B12 | 500C12 | 500D12 | 500E12 |
| 1000 W | 1000H12 | 1000A12 | 1000B12 | 1000C12 | 1000D12 | 1000E12 |
| 2500 W | 2500H12 | 2500A12 | 2500B12 | 2500C12 | 2500D12 | 2500E12 |
| 5000 W | 5000H12 | 5000A12 | 5000B12 | 5000C12 | 5000D12 | 5000E12 |
| 10 kW | 10KH12 | 10KA12 | 10KB12 | | | |
| 25 kW | 25KH12 | 25KA12 | 25KB12 | | | |

Note - Transmission line power rating should not be exceeded.

4700A THRULINE® Wattmeter

Table 1-5/8B - 100 μ amp

| Power Range | Frequency Band (MHz) | | | |
|-------------|----------------------|--------|---------|----------|
| | 2-30 | 50-125 | 100-250 | 400-1000 |
| 300 W | | 300B1 | 300C1 | 300E1 |
| 600 W | | 600B1 | 600C1 | 600E1 |
| 1500 W | 1500H1 | 1500B1 | 1500C1 | 1500E1 |
| 3000 W | 3000H1 | 3000B1 | 3000C1 | 3000E1 |
| 6000 W | 6000H1 | 6000B1 | 6000C1 | 6000E1 |
| 15 kW | 15KH1 | 15KB1 | | |

Note - Transmission line power rating should not be exceeded.

Table 1-5/8BB - 30 μ amp

| Power Range | Frequency Bands (MHz) | |
|-------------|-----------------------|-------------|
| | 50-125 MHz | 100-250 MHz |
| 300 W | 300B12 | 300C12 |
| 600 W | 600B12 | 600C12 |
| 1500 W | 1500B12 | 1500C12 |
| 3000 W | 3000B12 | 3000B12 |
| 6000 W | 6000B12 | 6000C12 |

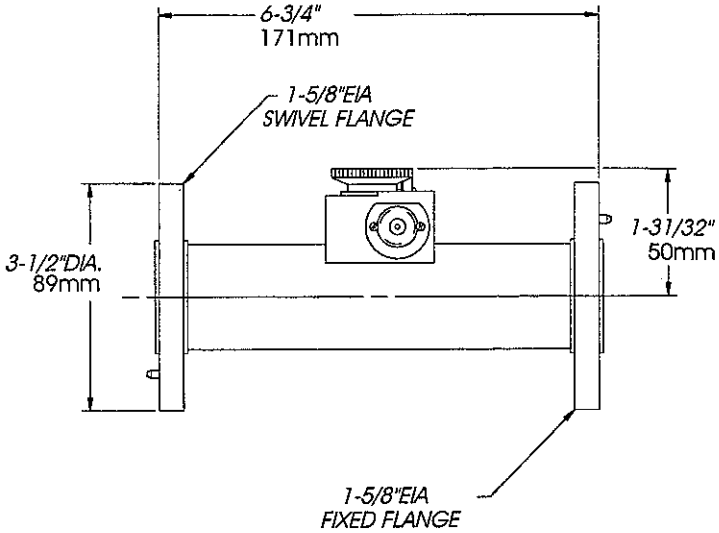
Note - Transmission line power rating should not be exceeded.

Table 1-5/8C - 100 μ amp

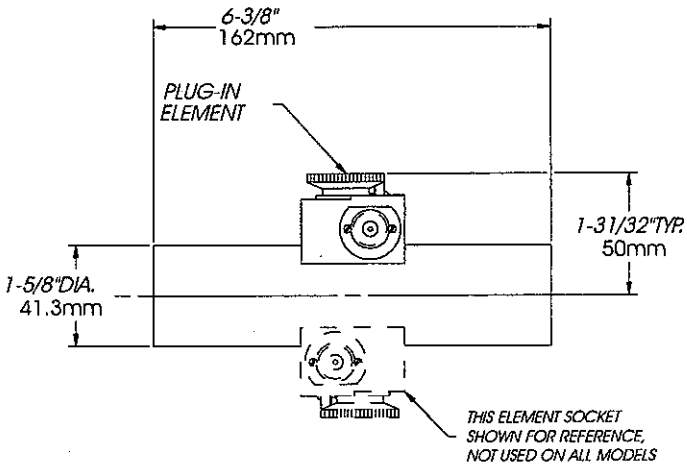
| Power Range | Frequency Band (MHz) | | |
|-------------|----------------------|--------|---------|
| | 25-60 | 50-125 | 100-250 |
| 8000 W | 8000A1 | 8000B1 | 8000C1 |

Note - Transmission line power rating should not be exceeded.

4700A THRULINE® Wattmeter



MODEL 4712A



MODEL 4715A

Figure 1-1. Outline Drawing of Line Sections

4700A THRULINE® Wattmeter

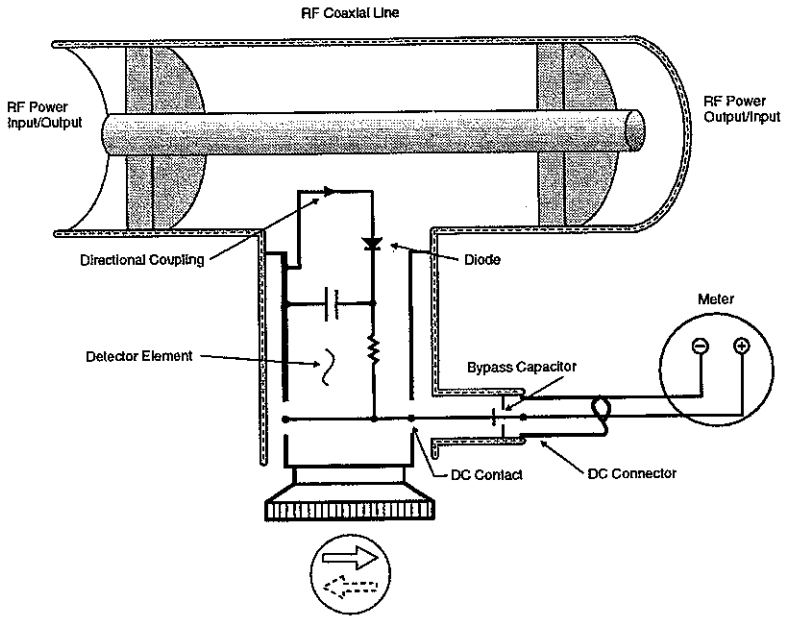


Figure 1-2. Schematic Diagram - Element

SECTION II. INSTALLATION

2.1. LOCATION

The measuring section is installed in a 1-5/8 inch 50 ohm coaxial transmission line where measurement is desired and the insertion coupling is feasible. Be sure that all exposed electrical surfaces, both on the metal contacts and insulators, are thoroughly clean and free of moisture before making the installation.

2.2. COUPLING KITS

The line section is a short length of matching 1-5/8 inch coaxial transmission line. For Models 4712A, 4712-200A, 4712-037A, and 4715-300A the line section has bolted flanges that are fixed on one end and swivel type on the other. It is inserted into the existing transmission line with the aid of a coupling kit, P/N 4712-020.

For Models 4720A and 4723-200A, the line section is unflanged. It is inserted into the existing transmission line with the aid of an unpressurized straight coupling kit, such as the RCA MI-56156-4A or Prodelin No. 323-825.

2.3. MOUNTING

For the models with flanged line sections (Models 4712A, 4715-200A, 4712-037A, and 4715-300A Wattmeters) the center conductor anchor bullets, P/N 4712-021, mate with the center conductor of the 1-5/8 inch 50 ohm coaxial transmission line. This line should be fitted with 1-5/8 inch EIA flanges. It is permissible for the mating flanges of the stationary line to both be of the rigid type because the line section has a rigid type flange on one end and a swivel type flange on the other. Before fitting bolts to the coupling flanges make sure the measuring element socket is oriented for easy access to and operation of the Plug-In Element. Also, check that the center conductor anchor bullets have been positioned with insulators properly seated in the counterbores. Use eight suitable bolt assemblies for attachment. 5/16-18 x 1-1/2 nut and bolt assemblies are recommended. It is usually better to attach the fixed flange of the measuring section first. Tighten evenly all around to get a firm and uniform contact on the periphery of the outer conductor of both flanges. When properly installed the coaxial line should be continuous with no bends or offsets in its axial line.

For the models with unflanged line sections (Models 4720A and 4723-200A Wattmeters) the connector bullets mate with the center conductor of the 1-5/8 inch 50 ohm coaxial transmission line. Insert the bullets firmly in the center conductor of the line section and push them in until they bottom in the conductor. The insulator discs will approximately touch the inside face of the outer conductor. Slide the outer sleeves over the transmission line first and then insert the line section into the transmission line. Both bullets should be firmly seated in the center conductor with the ends of the line section butted snugly against the ends

4700A THRULINE® Wattmeter

of the transmission line. Then slide the outer sleeves over the junctures of the line section and the transmission line and tighten the clamping screws to complete the installation.

2.4. METER PLACEMENT

Connect the dc cable plug to the jack on the measuring element socket. Make certain that the connection is tight and clean to insure accurate readings (see Section V, Maintenance). The meter may be placed anywhere within the reach of the dc cable, but avoid locations that are dusty or subject to temperature extremes.

SECTION III. THEORY OF OPERATION

3.1. TRAVELLING WAVE VIEWPOINT

The best way to visualize the THRULINE® Wattmeter idea is from the Travelling Wave viewpoint on transmission lines, which illustrates that the voltages, currents, standing waves, etc., on any uniform line section are the resultants of two travelling waves, forward and reflected.

3.2. COUPLING CIRCUIT

The coupling circuit which samples the travelling waves is in the Plug-In Element. Energy will be produced in the coupling circuit of the element by both mutual inductance and capacitance from the travelling RF waves of the line section. Of course, the inductive currents will flow according to the direction of the travelling waves producing them.

The capacitive portion of these currents is naturally independent of the direction of the travelling waves. Therefore, it is apparent that the inductive portion of the current produced from the waves of one direction will add in phase to the capacitive portion of the current, and those of the opposite direction will subtract in phase. The additive direction is the forward or ARROW direction of the element.

The forward wave travels and its power flows from the source to the load. It has an RF voltage E_f and current I_f in phase, with $E_f / I_f = Z_o$.

The reflected wave originates by reflection at the load, travels and its power flows from the load back to the source. It has an RF voltage E_r and current I_r in phase, with $E_r / I_r = Z_o$.

Note that each component wave is mathematically simple and is completely described by a single figure for power, for instance:

$$W_f = \text{Watts Forward} = E_f^2 / Z_o = I_f^2 Z_o = E_f I_f$$

$$W_r = \text{Watts Reflected} = E_r^2 / Z_o = I_r^2 Z_o = E_r I_r$$

Z_o is the characteristic impedance of the uniform line, and simplifies matters by being a pure resistance, usually 50 ohms for useful lines. The main RF line circuit of the THRULINE® Wattmeter is a short piece of uniform air line section, whose Z_o is 50 ohms, in which accurate measurements may be made.

The electrical values of the element circuits are carefully balanced and so designed that the inductive current produced from the reverse direction wave will cancel its portion of the capacitive current almost completely. The result is a directivity always higher than 25 dB, which means that the element is highly

4700A THRULINE® Wattmeter

insensitive (nulled) to the reverse direction wave. By being highly directional, the THRULINE® Wattmeter is sensitive at either one of its settings, but to only one of the two travelling waves which produce standing waves by interference. THRULINE® Wattmeter measurements are also independent of their position along the standing waves. It may be said that the THRULINE® Wattmeter doesn't know, doesn't care, and doesn't need to care where it is along a standing wave. The circuitry of the element and its relationship to the other components of the wattmeter are illustrated in figure 1-2.

3.3. ELEMENT SOCKET

An accurately positioned socket for inserting a radio frequency coupling device, called a THRULINE® Plug-In Element, is mounted on the outer conductor. The line sections for 4715-200A, 4723-200A, and 4715-300A have two such sockets. The socket is precision bored to hold the rotatable element in its calibrated position, with a spring-loaded clasp to keep the element firmly seated. The machined step on the top face of the socket engages a stop-pin on the element. Rotary movement of the element is thereby restricted to 180 degrees and is stopped on the axial center line.

The measuring socket has a hole bored through the wall through which an insulated phosphor bronze contact finger projects. The Plug-In Element has terminals on diametrically opposite sides of its body, so that pickup can be made from either side. A small silvered button tip can contact the element only in the precise forward and reflected measuring positions, against the end stops. A specially designed jack mounted on the side of the socket mates with the plug on the dc cable furnished with the read-out meter. The dc jack assembly has a built-in filter capacitor shunted across the meter circuit. This more fully protects meter readings against the adverse effects of any stray RF energy generated in the Plug-In Element. The line section is bright silver plated over practically all of its metal parts.

3.4. MATCHING

CAUTION

The wattmeter, the THRULINE® element and the RF line section, collectively referred to as THRULINE® in the remainder of this section, all have matching serial numbers. Do not intermix these parts with parts from other THRULINE® equipment.

The scale on the read-out meter reads full scale for the power rating stamped on the cap of the Plug-In Element. The meter box, the Plug-In Element, and the THRULINE® Section are all stamped with matching serial numbers. The equipment is supplied as a matched and calibrated set and the parts, particularly the elements, should not be interchanged with any other Series 4700A unit. Such an interchange of the measuring elements could produce readings with an error greater than the stated 5 percent of full scale accuracy.

3.5. LOAD POWER

Power delivered to and dissipated in a load is given by:

$$W_L = \text{Load in Watts} = W_f - W_r$$

Where appreciable power is reflected, as with an antenna, it is necessary to subtract the reflected power from the forward power to get the effective power. This correction is negligible, less than 1 percent, if the loading device has a VSWR of 1.2 to 1 or less. Good load resistors, such as the 8700 Series RF Loads, will thus show negligible or unreadable reflected power.

VSWR scales, and their attendant controls for setting the reference point, have been intentionally omitted from the THRULINE® Wattmeter for two reasons.

- a. Why make something similar to a hypothetical dc volt ohmmeter with control potentiometers for the voltmeter multipliers? Even more complications arise when diodes at RF are involved.
- b. Experience using the THRULINE® Wattmeter on operating problems, such as transmitter tune-up, antenna matching etc., shows that the power ratio ϕ is no mean competitor, in practical usefulness, to the standing wave ratio $P = \text{VSWR}$.

4700A THRULINE® Wattmeter

A trial is suggested for a few days - forget VSWR and try thinking in terms of $\phi = W_r / W_t$ when the THRULINE® Wattmeter is used. It will be noted that even without bothering to calculate the ratio exactly the two meter readings, W_r and W_t , give an automatic mental impression which pictures the situation. Thus, in an antenna matching problem the main objective usually is to minimize W_r , and anything done experimentally to this end is noted directly when the THRULINE® Element is turned to the reflected position. Furthermore, the ratio of readings, even if only mentally evaluated, is a reliable guide to the significance of the remaining reflected power.

3.6. P VS. ϕ AND ITS SIGNIFICANCE

Since there are definite simple relationships between standing wave ratio P and the reflected/forward power ratio ϕ indicated by the THRULINE® Wattmeter, the latter may be conveniently used to measure VSWR.

$$p = \frac{1 + \sqrt{\phi}}{1 - \sqrt{\phi}} \quad \text{and} \quad \phi = \left[\frac{p - 1}{p + 1} \right]^2 \quad \begin{array}{l} \text{where } p = \text{VSWR} \\ \text{and } \phi = \frac{W_r}{W_t} \end{array}$$

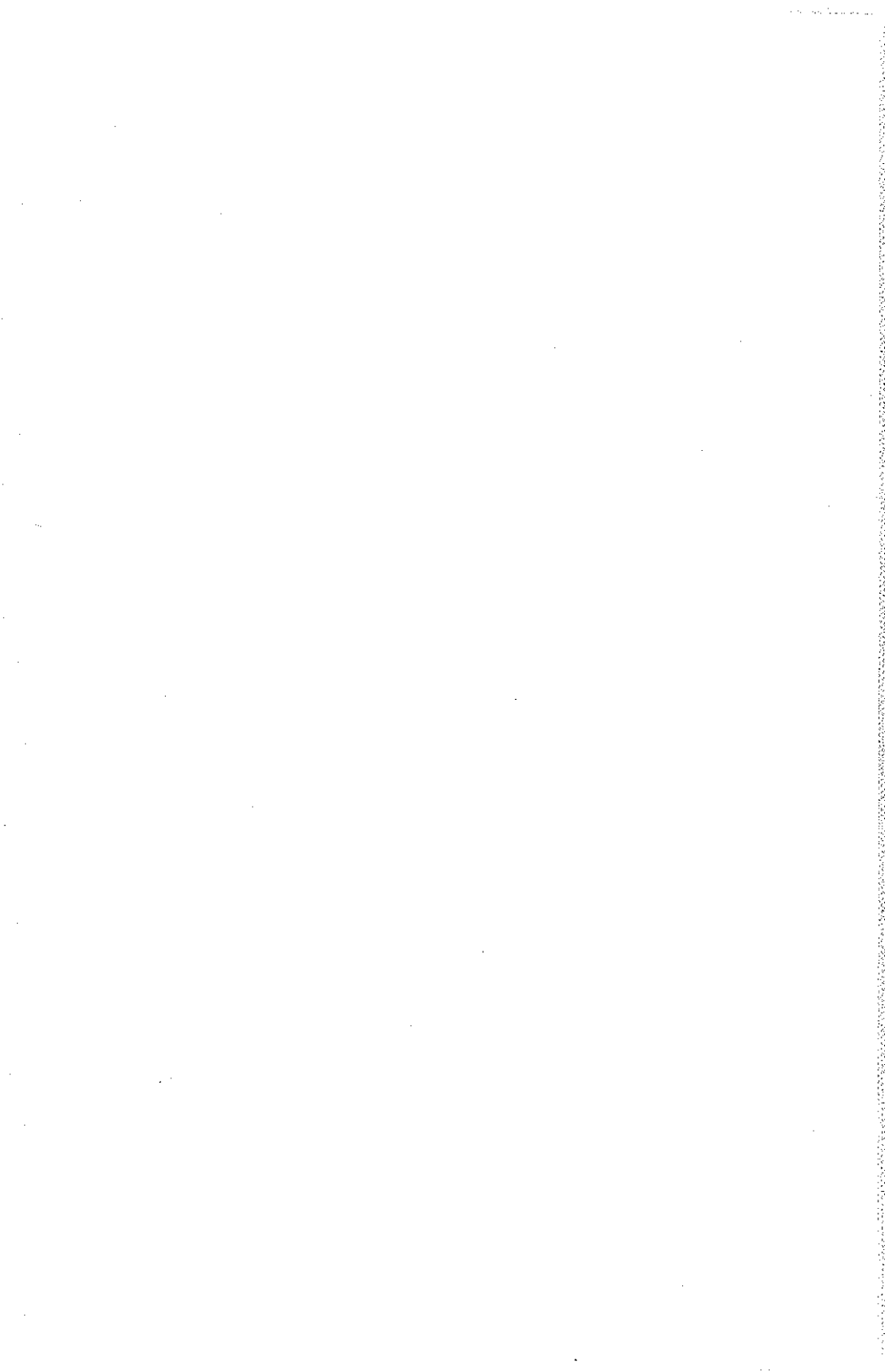
Note that around $\phi = 10$ percent, below which W_r will appear insignificant and may be hard to read, you are close to the commonly accepted lower limit $P = 2$. Trying to adjust to an even lower value of ϕ , in order to improve antenna match still further, becomes less and less worthwhile in many systems. Experimentally by using the THRULINE® Wattmeter it can be readily shown that reducing ϕ below 10 percent produces little in the way of increased W_t . TV transmitter antenna lines and VHF omnirange transmitters are among those systems that require much lower levels of reflected power but for reasons other than simple power transmission. A very small level of reflected power, e.g., $\phi = .06$ percent, corresponds to $P = 1.05$. With just a single element suitable for measuring W_r , detection of reflected power is possible down to about $\phi = 1$ percent ($P = 1.2$), providing W_t approaches full scale. However, measurement is possible only down to about $\phi = 5$ percent ($P = 1.5$).

3.7. MEASUREMENT AND MONITORING OF TRANSMITTER POWER

Little more need be said about this in view of the preceding load power discussion. The THRULINE® Wattmeter is useful for the continuous monitoring of transmitter output and is also helpful for the continuous monitoring of reflected power, for instance in checking intermittent antenna or line faults.

4700A THRULINE® Wattmeter

Like diode devices in general, the THRULINE® meter indicates the carrier component on amplitude modulation, with very little response to side band components added by modulation.



SECTION IV. OPERATING INSTRUCTIONS

4.1. USE AND FUNCTION OF CONTROLS

CAUTION

The wattmeter, the THRULINE® element and the RF line section, collectively referred to as THRULINE® in the remainder of this section, all have matching serial numbers. Do not intermix these parts with parts from other THRULINE® equipment.

The salient features of the THRULINE® equipment have been discussed in Section II, Installation, and Section III, Theory of Operation. Measurements are made by the insertion and operation of the Plug-In Elements previously mentioned. The elements will have a power range that matches one of the scales on the meter face and the major markings are the power values for that element. Elements are also marked for frequency range. The transmitter power and frequency must be within the range of the element used.

The ARROW on the Plug-In Element indicates the sensitive direction, i.e., the direction of power flow which the meter will read. Forward and reverse are directional terms used in reference to the THRULINE® Element and mean respectively the sensitive and null directions of the element. Rotate the element 180 degrees to reverse the sensitive direction. Forward and reflected are directional terms used in reference to the source load circuit. Note that the transmitter output line may be attached to either connector of the RF line section. It makes no difference which external RF connection is selected, since the elements are reversible and the RF circuit is symmetrical end for end. For Models 4715-200A, 4723-200A, and 4715-300A a FWD (Forward) and RFL (Reflected) selector switch is provided. Used in conjunction with the double socket line section included with these models, it makes measuring the desired power flow much more convenient.

4.2. INITIAL ADJUSTMENTS AND CONTROL SETTING

Before taking readings be sure that the meter pointer has been properly zeroed under no-power conditions. Direct power readings are made from the wattmeter dial. For double socketed line section models set the selector switch for the desired direction of power measurement.

4.3. START-UP

After the line section is properly installed in the transmission line and the dc connector cables from the element socket to the meter have been attached (see Section II, Installation), nothing more is required.

4700A THRULINE® Wattmeter

4.4. NORMAL OPERATION

Insert the appropriate element in the socket of the line section and rotate the element so that the ARROW on its nameplate is pointed away from the RF source for forward power and towards the source for reflected power. Turn on the RF source and read the power level indicated on the appropriate meter scale.

4.5. OPERATION UNDER ABNORMAL CONDITIONS

The elements for THRULINE® Wattmeters can withstand at least a 20 percent overload. If the power to be measured is greater, by a reasonable amount, than the maximum value of the element available, the THRULINE® Wattmeter and element may be used to give an indication of power flow even though the pointer is overranged and it is not possible to ascertain the true maximum power.

4.6. SHUTDOWN

Because these THRULINE® Wattmeters are passive devices and require no external source of power, they cannot be shut off. The RF source must be shut off instead.

4.7. EMERGENCY SHUTDOWN

WARNING

Never attempt to disconnect the transmission line while RF power is being applied. Leaking RF energy is a potential health hazard.

In case of an overload, it is possible to rotate the element to the midpoint between the forward and reflected positions and thereby electrically decouple the element from the meter. Do not remove the element while RF power is still flowing through the line section.

SECTION V. MAINTENANCE

5.1. TROUBLESHOOTING

As a brief guide to the operator in isolating occasional difficulties that may occur in the use of the THRULINE® Wattmeter, the following summary is included. The remedies for some are referenced to the text in this section or are self-evident.

| PROBLEM | POSSIBLE CAUSE | REMEDY |
|---|--|--|
| No meter indication | No RF power | Check RF source. |
| | ARROW on Plug-In Element pointing in wrong direction | Change position of element. |
| | No pickup from dc contact finger | Adjust, per paragraph 5.9. |
| | Open or short circuit | Replace defective cable on dc meter cable (RG-58/U). |
| Intermittent or inconsistent meter readings | Meter burned out or damaged | Return wattmeter, line section, and elements to the factory for meter replacement and recalibration. |
| | Faulty transmission line | Inspect line. |
| | Dirty dc contact on elements | Clean per paragraph 5.2, Cleaning. |
| | Sticky or defective meter | Return wattmeter, line section, and elements to the factory for meter replacement and recalibration. |

4700A THRULINE® Wattmeter

TROUBLESHOOTING [CONT.]

| PROBLEM | POSSIBLE CAUSE | REMEDY |
|------------------------------|---|-----------------------------|
| High VSWR or reflected power | Bad load or poor connectors | Replace load or connectors. |
| | Shorted or open transmission line | Have line serviced. |
| | Foreign material in the section or in RF connector bodies | See paragraph 5.5. |

5.2. CLEANING

WARNING

When using dry cleaning solvents, provide adequate ventilation and observe normal safety precautions. Many dry cleaning agents emit toxic fumes that may be harmful to your health, if inhaled.

If any of the contacts or line connectors become dirty, they should be wiped off with a clean cloth and a dry cleaning solvent. Use an aerosol contact cleaner that is self-drying, but forms no residue, on the inaccessible internal parts. Clean all contact areas and especially the exposed faces of the Teflon insulators.

It is particularly important to keep the mating surfaces of the socket and Plug-In Element clean. This applies not only to the bore of the socket and the circumference of the THRULINE® Element body, but most particularly to the bottom rim of the element body and the seat at the base of the socket in the line section. Also, check the dc contacts on the THRULINE® Element. They should be clean and smooth. These parts can be carefully cleaned with a soft cloth and contact cleaner as mentioned. There must be a good contact between the base of the Plug-In Element and its socket to assure stable operation of the THRULINE® Wattmeter.

5.3. INSPECTION

Inspect the THRULINE® unit from time to time for cleanliness and proper adjustment per paragraphs 5.2, Cleaning and 5.4, Preventive Maintenance. Make sure all connections are clean and tight. Check the meter with RF power off and adjust the ZERO setting if necessary.

5.4. PREVENTIVE MAINTENANCE

With the simple construction and generally self-contained nature of the THRULINE® equipment, there is only a moderate amount of maintenance required. One of the major precautions is in handling. Use reasonable care and do not drop the THRULINE® equipment, especially the Plug-In Elements.

The main factor in maintenance is care and cleanliness. The element socket should be kept plugged as much as possible to prevent the intrusion of dust. If a Plug-In Element is to be used for this purpose, use the highest power element available. The element should be positioned so that the ARROW is pointing midway between the FWD and RFL measuring positions. This will not only protect the meter by shunting the movement, but will also avoid exposing the element's crystal to dangerous potentials if the RF line section should be energized.

5.5. LINE SECTION CARE

CAUTION

Under no circumstances attempt to remove the RF center conductor. It is tightly frozen in place and any attempt to remove it will ruin the assembly.

If there is any evidence of contamination inside the RF line section, the reachable portions should be cleaned and the interior carefully blown out. Keep all connections tight, and keep the nut of the meter cord plug turned tight on the line section dc jack. This connection may often be serviced by simply loosening the nut of the dc plug, rotating the body several times through a fraction of a turn and retightening the knurled nut securely.

5.6. DISASSEMBLY

There is no disassembly possible of the THRULINE® unit other than the disconnection of the line section and the dc cable (see Section II, Installation).

4700A THRULINE® Wattmeter

5.7. REASSEMBLY

See paragraph 5.6 .

5.8. REPAIRS

There are no replacement parts furnished with this equipment. As previously mentioned, components of these matched units cannot be interchanged or individually replaced. The only replaceable portions of the line section are standard parts of coaxial line fastenings.

Repairs beyond what are covered in this instruction book will require return of the equipment to the factory for service.

5.9. CONTACT ADJUSTMENT

In cleaning the socket bore the operator should be careful not to disturb the spring finger of the dc contact. It is important that the operating position of this part be properly maintained. If the spring finger of the dc contact requires adjustment, it may be done manually if carried out with care. The tip must be positioned far enough out to maintain good contact with the element but not so far as to interfere with easy entry of the element body. The dc jack, with attached spring finger, may be detached for service by removing the two 4-40 fillister head machine screws which fasten it to the side of the RF line section. Then lift off the jack assembly carefully to avoid losing the small Teflon insulating bead that straddles the base of the phosphor bronze spring and nests in a counterbore on the side of the RF body. When replacing the assembly, be sure that the bead is again properly inserted.

SECTION VI. PREPARATION FOR RESHIPMENT

6.1. ELEMENTS

The elements can be left in the sockets of the line section with their ARROWS turned midway between the measuring positions. Two additional elements can be placed in the storage sockets in the sides of the meter housing, if so equipped. Any additional elements should be well padded and wrapped before being put in the shipping container.

6.2. LINE SECTION

Wrap the connectors on the flanged models with padding and tape them securely in place. Cover both ends of the line section and the socket to keep out dust and foreign material. Place the line section in a sturdy shipping container such as a corrugated paper box.

6.3. DC CABLES

Pad and wrap the dc connector plugs and then coil the cables tightly. For convenience place them in the open back of the meter housing.

6.4. METER

Cover the meter face with padding to protect the glass window, then wrap the housing and place it in the same box as the line section.



SECTION VII. STORAGE

7.1. GENERAL

No special preparations for storage are necessary other than to cover the equipment to keep out dust and dirt. Store these units in a dry and dust-free environment where the ambient temperature will remain within the -40°C to $+45^{\circ}\text{C}$ (-40°F to $+113^{\circ}\text{F}$) working range of the loads. For an extra precaution, leave an element in the socket with the ARROW turned midway between the measuring positions.



SECTION VIII. REPLACEMENT PARTS LIST

8.1. SERIES 4700A

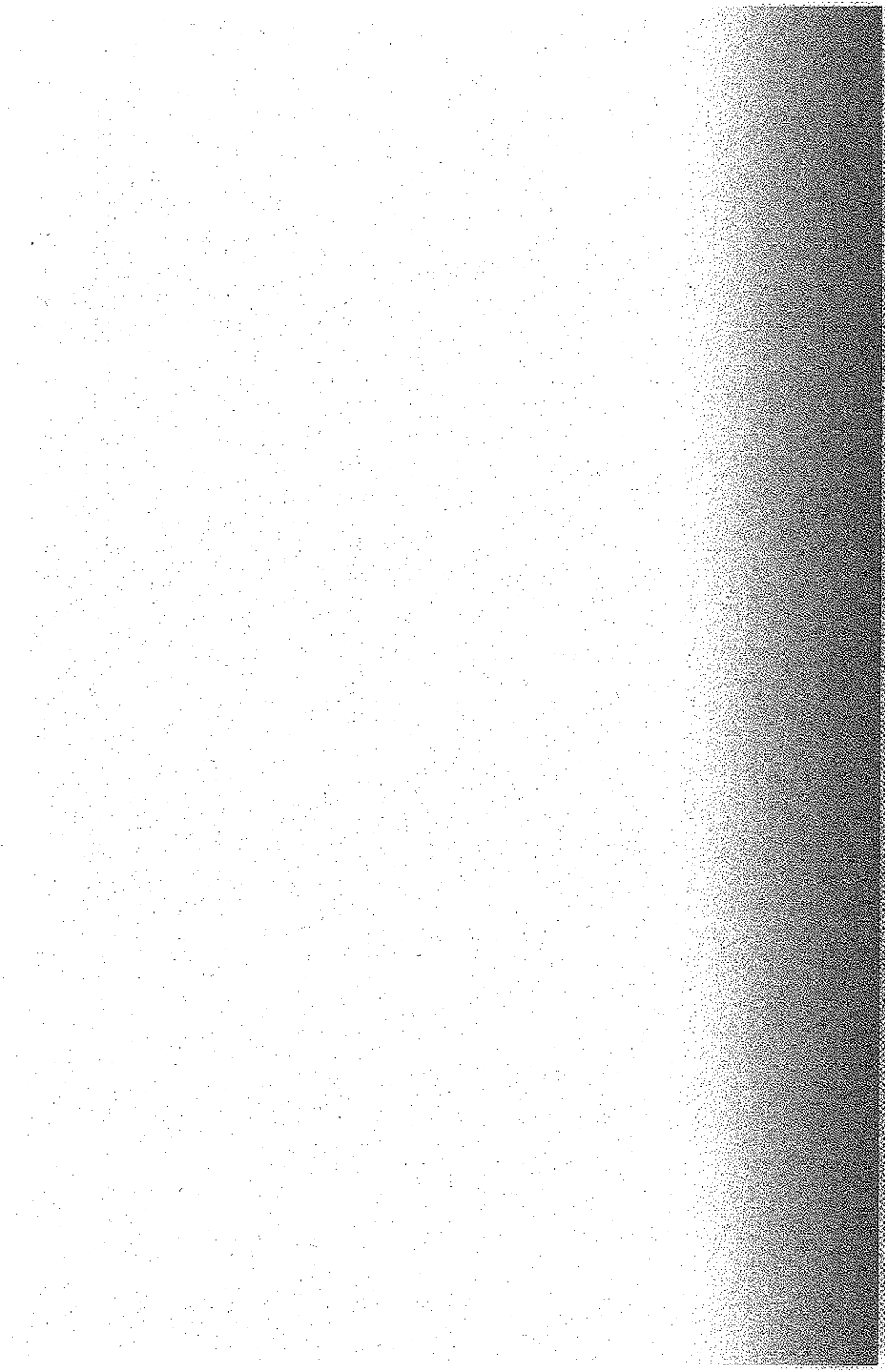
As mentioned previously, there are no field replaceable parts except the following:

| ITEM | QUANTITY | DESCRIPTION | PART NUMBER |
|------|----------|-----------------------|-------------|
| 1 | 1 or 2 | DC connector plug | 7500-076 |
| 2 | 1 or 2 | Cable assembly | 6810-214-1 |
| 3 | 1 or 2 | DC connector assembly | 4230-010 |

The following listings are for reference only:

| ITEM | QUANTITY | DESCRIPTION | PART NUMBER |
|------|----------|---|-------------|
| 4 | 1 | Meter Models 4712A, 4715A, 4715-200A 4720A, 4723-200A | 2150-230 |
| | | Models 4712-037A, 4715-300A | 2150-259 |
| | | Models for 8 kW use | 2150-268 |
| 5 | 1 | Meter and housing assembly Models 4712A, 4720A | 6810-309-7 |
| | | Models 4715-200A, 4723-200A | 6810-220 |
| | | Model 4712-037A | 6810-307 |
| | | Model 4715-300A | 6810-230 |
| | | Models with 8 kW wattmeter combinations | 6810-265 |

- NOTES -



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