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. These precautions must be thoroughly understood and apply to all phases of operation and maintenance.

WARNING

Keep Away From Live Circuits

Operating Personnel must at all times observe general safety precautions. Do not replace components or make adjustments to the inside of the test equipment with the high voltage supply turned on. To avoid casualties, always remove power.

WARNING

Shock Hazard

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

WARNING

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.

WARNING

Safety Earth Ground

An uniterruptible 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.

WARNING

Resuscitation

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

WARNING

Remove Power

Observe general safety precautions. Do not open the instrument with the power on.

Safety Symbols

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

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

The caution symbol appears on the equipment indicating there is important information in the instruction manual regarding that particular area

☞ **Note:** *Calls attention to supplemental information.*

Warning Statements

The following safety warnings appear in the text where there is danger to operating and maintenance personnel, and are repeated here for emphasis.

WARNING
Leaking RF energy is a potential health hazard. Never attempt to connect or disconnect equipment from the transmission line while RF power is being applied. Severe burns, electrical shock, or death can occur.

On page 11.

WARNING
When working with RF powers of 200 watts or more, the potential of the center conductor of the line section will be over 100 volts. Do not touch the center conductor while RF power is on.

On page 13.

Caution Statements

The following equipment cautions appear in the text and are repeated here for emphasis.

CAUTION
For low reflection measurements, do not rotate the reflected power element to read forward power. Damage to the element or wattmeter could result.

On page 7.

CAUTION
Handle elements with care. Calibration could be disturbed if they are dropped.

On page 11.

CAUTION
Do not attempt to remove the RF center conductor. This will damage the line section.

On page 20.

Safety Statements

USAGE

ANY USE OF THIS INSTRUMENT IN A MANNER NOT SPECIFIED BY THE MANUFACTURER MAY IMPAIR THE INSTRUMENT'S SAFETY PROTECTION.

USO

EL USO DE ESTE INSTRUMENTO DE MANERA NO ESPECIFICADA POR EL FABRICANTE, PUEDE ANULAR LA PROTECCIÓN DE SEGURIDAD DEL INSTRUMENTO.

BENUTZUNG

WIRD DAS GERÄT AUF ANDERE WEISE VERWENDET ALS VOM HERSTELLER BESCHRIEBEN, KANN DIE GERÄTESICHERHEIT BEEINTRÄCHTIGT WERDEN.

UTILISATION

TOUTE UTILISATION DE CET INSTRUMENT QUI N'EST PAS EXPLICITEMENT PRÉVUE PAR LE FABRICANT PEUT ENDOMMAGER LE DISPOSITIF DE PROTECTION DE L'INSTRUMENT.

IMPIEGO

QUALORA QUESTO STRUMENTO VENISSE UTILIZZATO IN MODO DIVERSO DA COME SPECIFICATO DAL PRODUTTORE LA PROZIONE DI SICUREZZA POTREBBE VENIRNE COMPROMESSA.

SERVICE

SERVICING INSTRUCTIONS ARE FOR USE BY SERVICE - TRAINED PERSONNEL ONLY. TO AVOID DANGEROUS ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS QUALIFIED TO DO SO.

SERVICIO

LAS INSTRUCCIONES DE SERVICIO SON PARA USO EXCLUSIVO DEL PERSONAL DE SERVICIO CAPACITADO. PARA EVITAR EL PELIGRO DE DESCARGAS ELÉCTRICAS, NO REALICE NINGÚN SERVICIO A MENOS QUE ESTÉ CAPACITADO PARA HACERIO.

WARTUNG

ANWEISUNGEN FÜR DIE WARTUNG DES GERÄTES GELTEN NUR FÜR GESCHULTES FACHPERSONAL. ZUR VERMEIDUNG GEFÄHRLICHE, ELEKTRISCHE SCHOCKS, SIND WARTUNGSARBEITEN AUSSCHLIEßLICH VON QUALIFIZIERTEM SERVICEPERSONAL DURCHZUFÜHREN.

ENTRENTIEN

L'EMPLOI DES INSTRUCTIONS D'ENTRETIEN DOIT ÊTRE RÉSERVÉ AU PERSONNEL FORMÉ AUX OPÉRATIONS D'ENTRETIEN. POUR PRÉVENIR UN CHOC ÉLECTRIQUE DANGEREUX, NE PAS EFFECTUER D'ENTRETIEN SI L'ON N'A PAS ÉTÉ QUALIFIÉ POUR CE FAIRE.

ASSISTENZA TECNICA

LE ISTRUZIONI RELATIVE ALL'ASSISTENZA SONO PREVISTE ESCLUSIVAMENTE PER IL PERSONALE OPPORTUNAMENTE ADDESTRATO. PER EVITARE PERICOLOSE SCOSSE ELETTRICHE NON EFFETTUARRE ALCUNA RIPARAZIONE A MENO CHE QUALIFICATI A FARLA.

RF VOLTAGE MAY BE PRESENT IN RF ELEMENT SOCKET - KEEP ELEMENT IN SOCKET DURING OPERATION.

DE LA TENSION H.F. PEAT ÊTRE PRÉSENTE DANS LA PRISE DE L'ÉLÉMENT H.F. - CONSERVER L'ÉLÉMENT DANS LA PRISE LORS DE L'EMPLOI.

HF-SPANNUNG KANN IN DER HF-ELEMENT-BUCHSE ANSTEHEN - ELEMENT WÄHREND DES BETRIEBS EINGESTÖPSELT LASSEN.

PUEDE HABER VOLTAJE RF EN EL ENCHUFE DEL ELEMENTO RF - MANTENGA EL ELEMENTO EN EL ENCHUFE DURANTE LA OPERACION.

IL PORTAELEMENTO RF PUÒ PRESENTARE VOLTAGGIO RF - TENERE L'ELEMENTO NELLA PRESA DURANTE IL FUNZIONAMENTO.

This manual covers the operating and maintenance instructions for the following models:

43	43P	4301	4305A	4431	4527
4521	4522	4526			

Changes to this Manual

We have made every effort to ensure this manual is accurate. If you discover any errors, or if you have suggestions for improving this manual, please send your comments to our Solon, Ohio factory. This manual may be periodically updated. When inquiring about updates to this manual refer to the part number and revision on the title page.

Literature Contents

Chapter Layout

Introduction — Describes the features of the 43 Wattmeter, lists equipment supplied and optional equipment, and provides power-up instructions.

Theory of Operation — Describes how the 43 Wattmeter works and

Installation — Describes how to set up and prepare the 43 Wattmeter for use.

Operation - All instructions necessary to operate the equipment appears in this chapter.

Maintenance — Lists routine maintenance tasks as well as troubleshooting for common problems.

Model Differences — Describes how each indivdual models vary from each other.

Specifcations — Specifications and parts information are included in this chapter.

Table of Contents

Chapter 1 Introduction

Purpose and Function

The 43 is an insertion-type RF wattmeter, designed to measure RF power and load match in 50 ohm coaxial transmission lines. It is intended for use with CW, AM, FM, and TV modulation, but not pulse modulation. When used in 50 ohm applications, the 43 has a maximum VSWR of 1.05 for frequencies up to 1000 MHz. The meter provides direct readings in watts with an expanded scale for easy reading. The scale is graduated for 25, 50, and 100 full scale. Elements are available in a variety of power and frequency ranges (see the Bird Electronic Corporation Catalog for details).

This manual covers the operation of the Bird 43 Thruline Wattmeter and its descendants. Two models have RF sampler ports, while the Bird 43P can measure peak power. The Bird 4520 series comes ready for panel mounting. Differences are discussed in Chapter 6, on page 27. Except where indicated, instructions and specifications for the 43 apply to other models also.

Performance Characteristics and Capabilities

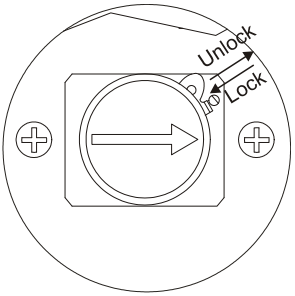
The Bird 43 is portable, with an attached carrying strap. It has an aluminum housing and an easily removed back cover, with bumpers on the base and back that allow the meter to stand or lie flat. For additional protection, the microammeter is specially shock mounted. A slotted screw on the lower front face of the meter is used to zero the pointer. Below the meter face, the RF line section protrudes slightly from the wattmeter housing with the element socket in the center.

A shielded cable connects the RF line section to the rest of the wattmeter. This lets you remove the line section from the wattmeter housing for custom installation and still make measurements. The RF line section is precision machined to provide the best possible impedance match to the transmission line under test. A formed phosphor-bronze spring finger protrudes into the element socket to make contact with the element.

At each end of the line section are Bird Quick-Change RF connectors that may be interchanged with any other Bird “QC” connector. The wattmeter housing does not interfere with connector changes.

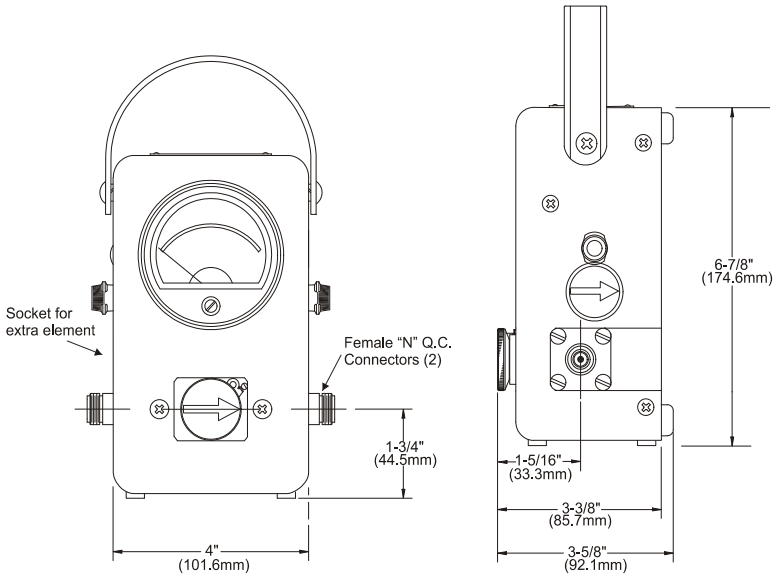
To make measurements, a Bird Plug-In Element is inserted into the line section socket and rotated against one of the stops. A small catch in the corner of the socket face presses on the shoulder of the element to keep it in proper alignment. This assures good contact between the spring finger and the element contact and between the lower edge of the element and the line section body (see Figure 1).

Figure 1 Securing an element



Contacts on opposite sides of the element connect with the spring finger when the element is in the forward or reverse position. This occurs when the stop pin on the element is against either stop and the catch is in place.

Figure 2 Bird 43 Thruline Wattmeter Outline Drawing



Chapter 2 Theory of Operation

Travelling Wave Viewpoint

The easiest way to visualize Thruline operation is from a travelling wave viewpoint. In transmission lines the voltages, currents, standing waves, etc., on any uniform line section result from the interaction of two travelling waves:

- **Forward Wave** (and its power) travels from the source to the load. It has RF voltage E_f and current I_f in phase, with $E_f / I_f = Z_o$.
- **Reflected Wave** (and its power) originates by reflection at the load and travels from the load back to the source. It has an RF voltage E_r and current I_r in phase, with $E_r / I_r = Z_o$.

Formulas

Each wave is mathematically simple and has a constant power:

Forward

$$W_f = WattsForward = E_f^2/Z_o = I_f^2 Z_o = E_f I_f$$

Reflected

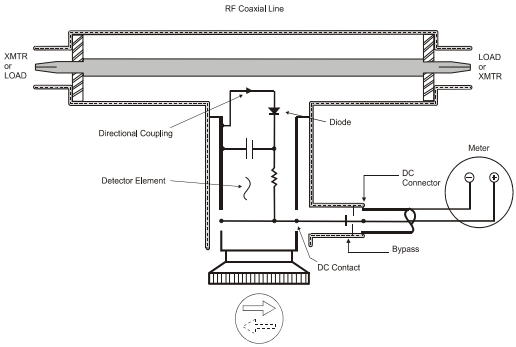
$$W_r = WattsReflected = E_r^2/Z_o = I_r^2 Z_o = E_r I_r$$

Note: *Z_o is the characteristic impedance of a uniform line section. For useful lines it is usually a pure resistance of 50 ohms. The RF circuit of the Bird 43 is a length of uniform air line with Z_o = 50 ohms.*

Coupling Circuit

The coupling circuit that samples the travelling waves is in the Bird Plug-In Element. The element circuitry and its relationship to the rest of the Bird 43 are illustrated in Figure 3.

Figure 3 Thruline Wattmeter Schematic



Current is produced in the coupling circuit by the travelling waves in the line section. Both inductive and capacitive coupling contribute to this. The inductive current flows in the direction of the travelling wave. The capacitive current is independent of the direction of the travelling wave. Therefore, the inductive current produced by one of the travelling waves will add in phase with the corresponding capacitive current, while that produced by the wave travelling in the opposite direction will subtract. The additive or “arrow” direction is assigned to the forward wave.

The electrical characteristics of the element are carefully adjusted so that, for the reverse travelling wave, the inductive current will completely cancel the capacitive current. The result is directivity greater than 25 dB. Thus, the element is sensitive at either of its settings, but to only one of the two travelling waves. Thruline Wattmeter measurements are also independent of position along the transmission line.

Like similar diode devices, the Bird 43 indicates the carrier component of amplitude modulation, with very little response to side band components added by modulation.

Load Power

For loads with a VSWR of 1.2 or less, the power dissipated in a load (W_l) is equivalent (with less than one percent error) to the forward power (W_f). When appreciable power is reflected, as with an antenna, it is necessary to use the exact load power which is given by:

$$W_1 = WattsIntoLoad = W_f - W_r$$

Good load resistors, such as Bird Termaline loads, will give negligible reflected power.

Standing Wave vs. Travelling Wave Viewpoint (ρ vs. ϕ)

As mentioned previously, the Thruline Wattmeter reacts to forward and reverse travelling waves to measure power in a transmission line. The standing wave viewpoint, also widely used, is highly developed both in theory and in practice. This viewpoint can be traced to the early use of slotted transmission lines.

The slotted line measures the standing wave ratio by mechanically positioning a voltage detector at peaks and nulls along a length of line section. Its drawbacks are that it is usually too long, too expensive for good accuracy, not portable, and too slow. These problems grow rapidly as the measurement frequency drops below 1000 MHz. The Thruline Wattmeter by comparison is fast, convenient, and accurate. It provides the same information as a slotted line with the exception of the phase angle of the reflection coefficient (distance, load to minimum).

The simple relationships:

$$\rho = \frac{1 + \sqrt{\phi}}{1 - \sqrt{\phi}}$$

and

$$\phi = \left[\frac{\rho - 1}{\rho + 1}\right]^2$$

Note: *Where r = VSWR and f = Wr / Wf*

These can be used to convert between the standing wave ratio (ρ) and the reflected/forward power ratio (ϕ), which can be directly read from the Thruline Wattmeter. The relationship between ρ and ϕ is graphed in Figure 4 and Figure 5.

Note: *Attenuation, measured in dB, can be derived from the power ratio by the equation* $N_{db} = 10 \log \phi$.

VSWR scales and their attendant controls for setting the reference point have been intentionally omitted from the Bird 43. Experience using the Thruline Wattmeter for transmitter tune-up, antenna matching, etc. will show that the power ratio measurement is as useful in practice as the standing wave ratio.

A trial is suggested – forget about VSWR for a few days and think in terms of $\phi = W_r / W_f$. The two meter readings, W_r and W_f, give a useful, approximate picture of the results without bothering to calculate the power ratio exactly. Consider that, for an antenna matching problem, the main objective usually is to minimize W_r. Anything done experimentally to this end will be seen when the element is turned to the reflected power position.