September 1979

HOT SHOT™

RATIO-SCOPE® 5

TWO-COLOR PYROMETER

OWNER'S MANUAL

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OWNER'S MANUAL
RATIO-SCOPE 5
TWO COLOR PYROMETER

This "Change Notice" applies to all Hot Shots starting with S/N 13185 and is a supplement to the owner's manual dated December, 1978.

Table of Contents:

Section 1.1 - General

Hot Shot units starting with S/N 13185 have a new detector-heater for improved stability and a single test point TI for simpler calibration check and adjustment.

Section 1.4 - Features and Capabilities, Par 3.

Hot Shot units starting with S/N 13185 have a new detector-heater for improved stability.

Battery operating time with the detector-heater is 4 hours of continous operation on internal Ni Cad battery.

An Extended Life Battery Pack is available as an option which increases the operating time to 12 hours.

Section 2.3 - Environment Requirements, Power Requirements, Par 1.

Rechargeable battery operation (internal Ni Cad battery) for units with detector-heater is up to 4 hours continous operation.

WARNING: When Hot Shot has detector-heater, charger Model No. 9100-2113 can only be used to charge the battery. Place power switch in off position. Remove charger when using instrument otherwise it may overheat.

A heavy duty charger unit will be available at a later date which can charge and operate the instrument at the same time for "on line" continous use.

Hot Shot units without detector-heater can use charger Model 9100-2113 for "on line" continous operation with charger connected.

Section 5.2 - Description of Controls

Power Switch (Off/On/TI)
Hot Shot units starting with S/N 13185 have only one test postion TI.

Cont.

Section 5.3.1 - Pre-Measurement Procedure

Step (1) - Check serial number to identify if instrument has detector-heater.

If unit does not have heater, proceed with Step (1) as is.

If unit has detector-heater, allow at least 5 minutes warm-up time, then proceed with the rest of Step (1).

Step (2) - No Change

Step (3) - Check mode switch to identify if instrument has two (TI, T2) or one (TI) test position.

If unit has two (2) test positions, proceed with Step (3) as is.

If unit has one (1) test position, instruction applies to TI.

Section 5.3.5 - Post Measurement Procedure

NOTES: 1) For units with detector-heater, battery charge will last (4) hours of continous operation.

Section 8.3 - Battery

Paragraph 1 - Units with detector-heater should hold their charge for four (4) hours of continous operation.

Section 9.5 - Internal Test Lamp

Hot Shots starting with S/N 13185 have only one test position TI to simplify operation of the instrument. This test point is at a temperature slightly above mid range. (>2000°F)

Section 9.7 - External Batteries and Optional Charger

Paragraph 9.8.1 - Extended Life Battery Pack

A new optional battery pack is available and is especially recommended for instruments with the new detector-heater. The Extended Life Battery Pack provides 12 hours of continous operation compared to 4 hours using only the internal Ni Cad batteries from full charge. The battery pack is simple to use requiring that it only be plugged into the "charger connector" on the Hot Shot handle. The battery pack is rechargeable with its own charger.

SECTION 1

INTRODUCTION

1.1 GENERAL

This manual contains instructions for operationg the Ratio-Scope® 5 (ROS 5) infrared two-color pyrometer.

1.2 PURPOSE

The purpose of the ROS 5 two-color optical pyrometer is to perform accurate and reliable non-contact temperature measurements of various objects. The instrument can be used to monitor and record temperature and is fully portable.

1.3 TWO-COLOR PYROMETER

The ROS 5 is a two-color optical pyrometer which detects radiation in the near infrared region of the spectrum. A two-color pyrometer has a great advantage over a single-color pyrometer.

The main advantages of the two-color pyrometer arise from the fact that it measures the ratio of the energy around two wavelengths (two colors). The single-color pyrometer, on the other hand, measures the energy received in a band around one wavelength. Any situation which alters the amount of detected energy will therefore, affect the temperature indication of the single-color pyrometer. The response of the two-color pyrometer, however, will not be affected by the change in detected energy. This is because the ratio of the detected energy is not likely to change assuming that the wavelengths are properly chosen.

The most important factors which affect the energy detected by the pyrometer are: adverse viewing conditions; unknown or changing emissivity; targets which do not fill the field-of-view; and changes in the selected size of the field-of-view. These factors are discussed in detail in Section 3.6.

Section 3 of this manual contains a detailed discussion of the principles of radiation pyrometry and a comparison of the three main types of pyrometers.

1.4 FEATURES AND CAPABILITIES

The Ratio-Scope® 5 is a light-weight one-piece, hand held instrument. The target temperature (with unit) and operator assist messages can all be seen while sighting the target through the eyepiece.

The Ratio-Scope® 5 is fully "human engineered" for ease of holding, viewing, and adjusting controls.

The instrument is completely battery operated for up to eight (8) hours of continuous operation. The battery is rechargeable. The instrument can also be used while recharging or with external batteries for longer operation time.

The design of the infrared detecting system and the electronic circuitry reflects Capintec Instruments many years of experience in the field of two-color optical pyrometry. The instrument utilizes patented electronic ratioing techniques to automatically correct for variations in target intensity, emissivity, and interfering dust, etc.

Although the Ratio-Scope® 5 is built to withstand the rigors of an industrial enviornment (such as steel making), it also possesses the capabilities required in sophisticated research applications.

The output of the Ratio-Scope® is linear.

The ROS 5 can perform accurate measurements over a wide range of temperatures. The instrument can measure temperatures as high as 2000°C (3600°F) and as low as 650°C (1200°F).*

The ROS 5 optical system features Through-the-Lens sighting, with adjustable field-of-view for large target average readings or small target localization.

The operation of the Ratio-Scope® 5 is quite simple and straight-forward. There are controls to verify proper instrument functioning and optional controls to adjust some of the internal parameters to meet special needs of the user.

*See Section 5.3 for details

SECTION 7

FUNCTIONAL DESCRIPTION

7.1 GENERAL

The Ratio-Scope® 5 is a fully portable, one-piece, hand held instrument.

A block diagram of the ROS 5 is shown in Figure 7-1. For convenience, the instrument will be discussed in two parts: the Sensor System and the Control Circuitry.

7.2 SENSOR SYSTEM

The sensor system consists of the optical system, the sensors, and the (optional) temperature regulation circuit.

7.2.1 OPTICAL SYSTEM

The optical system is shown schematically in Figure 7-1.

When the object lens is aimed at a target, radiation emitted from the surface of the target enters the sensing assembly.

The function of the object lens is to collect light and to image the target on the plane of the Field-of-View adjusting Iris so that the desired portion of the target can be selected by adjusting the opening of the Field-of-View Iris.

The f-stop (lens aperture; a lens with adjustable f-stop is optional) is set at 2.8 except for the measurement of extremely high temperature and when the Gain Control Adjustment is out of range.

Any high quality lens, designed for camera use (including zoom lens) with type "T" mounting may be used as an object lens. Substitution of lens may, however, alter the calibration of the instrument. When a lens has been substituted or close-up lenses have been added, it should be determined if any alteration in the calibration has occurred. This can be accomplished by comparing a target temperature measurement made with the original lens and a measurement

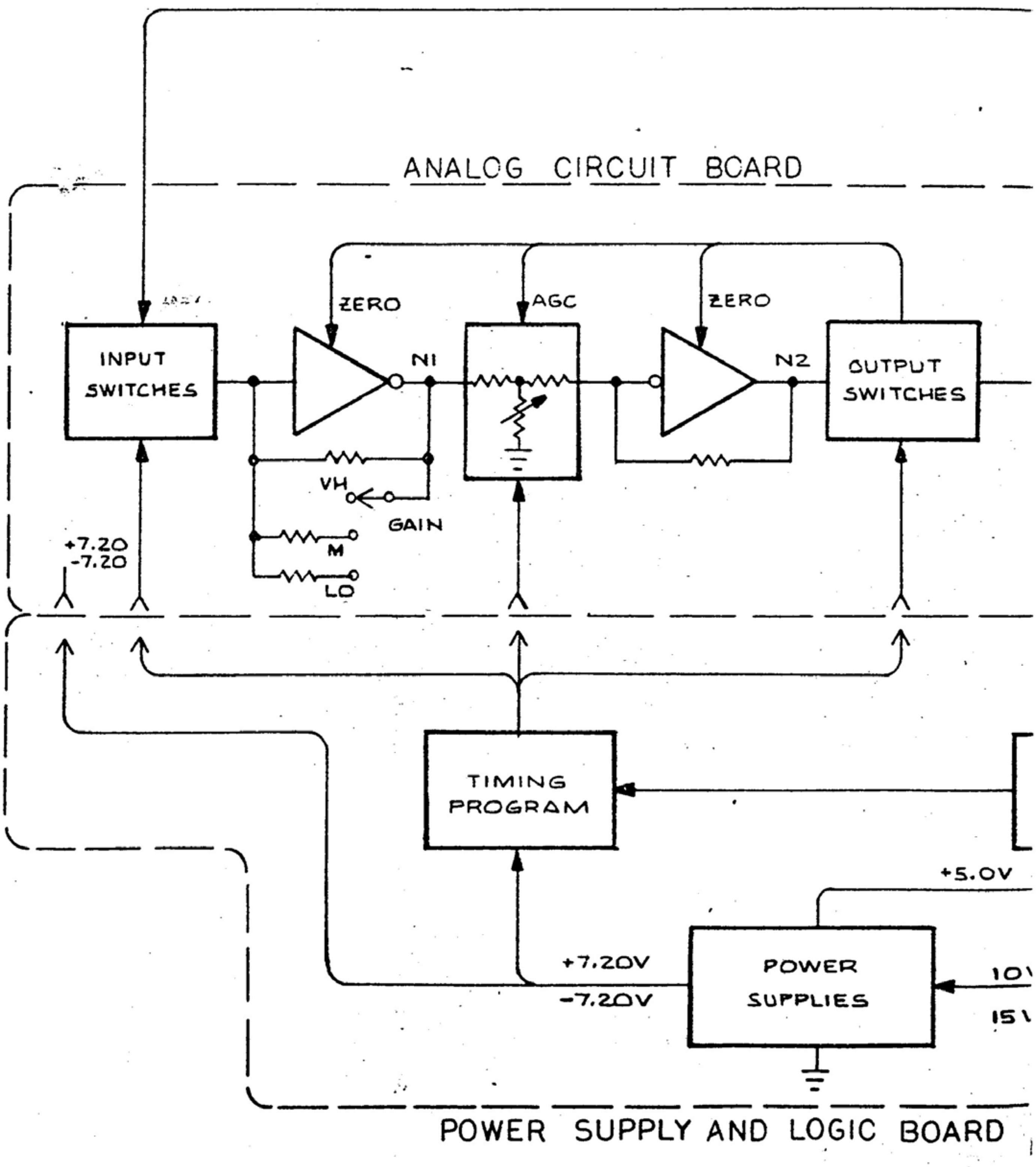
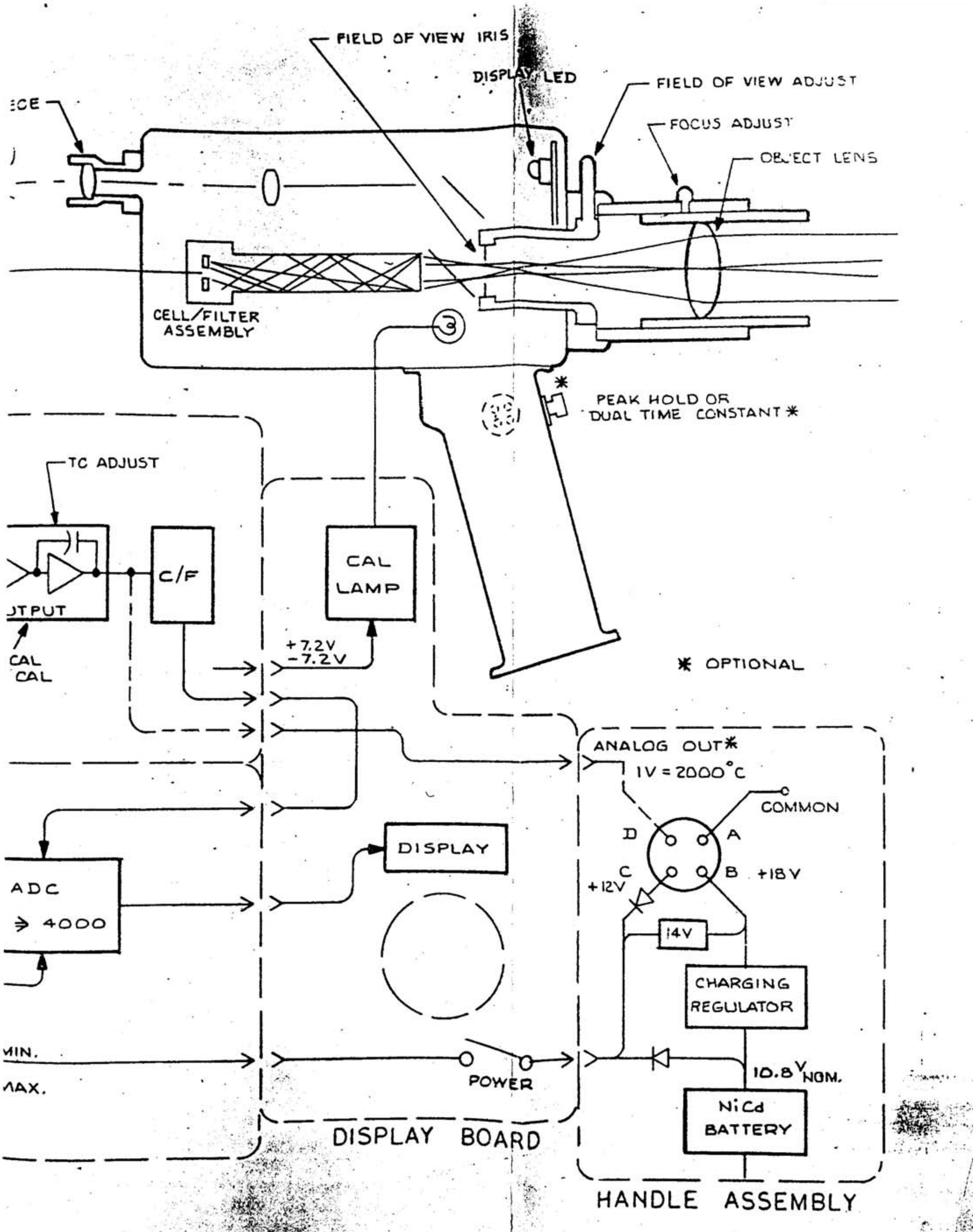

ANALOG CIRCUIT BOARD
INPUT SWITCHES
ZERO
N1
AGC
ZERO
N2
OUTPUT SWITCHES
VH
GAIN
M
LO
+7.20
-7.20
TIMING PROGRAM
+5.0V
POWER SUPPLIES
+7.20V
-7.20V
POWER SUPPLY AND LOGIC BOARD

FIG. 7-1 BLOCK



FIELD OF VIEW IRIS
DISPLAY LED
FIELD OF VIEW ADJUST
FOCUS ADJUST
OBJECT LENS
CELL/FILTER ASSEMBLY
PEAK HOLD OR DUAL TIME CONSTANT *
TC ADJUST
C/F
CAL LAMP
+7.2V
-7.2V
CAL
CAL
* OPTIONAL
ANALOG OUT*
1V = 2000°C
COMMON
D
A
C
B
+12V
+18V
14V
DISPLAY
ADC
4000
CHARGING REGULATOR
POWER
10.8V NOM.
NiCd BATTERY
MIN.
MAX.
DISPLAY BOARD
HANDLE ASSEMBLY

AGRAM, ROS-5

3.5 METHODS OF MAKING RADIATION MEASUREMENTS (PYROMETRY)

In spite of the aforementioned difficulties, the radiation laws have been used as the basis for pyrometers, i.e., instruments to measure temperature. The three main types of instruments will be discussed below.

3.5.1 TOTAL RADIATION PYROMETER

Total radiation pyrometers attempt to measure the radiant energy coming from a body over as wide a range of wavelengths as practically possible. The theory governing the total radiation pyrometer assumes that radiation from all wavelengths is detected. This, however, is not possible in a real situation.

In addition, if any substance that might absorb or scatter radiation is placed between the material and detector, radiation at some of the wavelengths will not reach the detector and the measurement will therefore be affected.

In order to obtain a correct reading with the total radiation pyrometer, the total emissivity of the material whose temperature is being measured must be known. If the total emissivity can be estimated, then the error in the measurement is dependent upon the error in the estimation. Of course, if the total emissivity is completely unknown, a very large error may exist. It should be recalled that the total emissivity depends upon temperature thus, complicating the estimation of total emissivity.

3.5.2 BRIGHTNESS (SINGLE-COLOR) PYROMETER

A brightness (or single-color) pyrometer measures the energy intensity emitted in a narrow band about a fixed wavelength. Although the brightness pyrometer is not as sensitive as the total radiation pyrometer, it could be more accurate because it might be possible to select a wavelength where the spectral emissivity does not

3.5.2 (cont'd)

vary with temperature as much as total emissivity. The error is also reduced due to the large non-linear characteristics of radiated energy as the temperature of the body changes. Still, in order to get an accurate measurement, the spectral emissivity should be known in the region of the chosen wavelength.

Other problems associated with the single-color pyrometer will be discussed in Section 3.6.

3.5.3 TWO-COLOR OR RATIO PYROMETER

It can be seen from the above discussion that the total radiation pyrometer and the brightness pyrometer are very dependent upon an emissivity whose exact value depends on temperature, surface conditions and other variables which are difficult to determine. The two-color or ratio pyrometer was developed to eliminate this direct dependence.

The ratio pyrometer detects the radiation emitted in narrow bands around two wavelengths. These bands are separate, but not too far apart. The quantity measured by the two-color pyrometer is the energy emitted in a band about the first wavelength divided by the energy in a band about the second wavelength; thus the name ratio pyrometer. This ratio of energies depends upon the ratio of the spectral emissivities at the two wavelengths instead of the absolute spectral emissivity.

The dependence of the two-color pyrometer on the ratio of the detected energy, instead of on the absolute detected energy, also eliminates other disadvantages of the brightness and total radiation pyrometers. This will be discussed in detail in Section 3.6.

SECTION 4

SPECIFICATIONS

4.1 GENERAL

Performance specifications are listed in this section. Environmental, physical and input power requirements are shown in Section 2.

Specifications are for an ambient temperature of 22°C (72°F) unless otherwise specified.

DISPLAY

Digital Display.

The instrument will be calibrated over one of the following spans within the over-all temperature range:

a) 500°C (1000°F): standard

b) 1000°C (2000°F): optional

See Section 9.2 for details and examples

The calibrated span for the particular instrument will be indicated on top of the Ratio-Scope®.

OVER-ALL TEMPERATURE RANGE

Standard Range: 800°C - 1800°C (1400°F - 3400°F)

Optional Range: 650°C** - 2000°C (1200°F** - 3600°F)

** for a large black body radiator

REPEATABILITY (Short Term Stability)

±[5°C (9°F) + 0.2% of temperature readings] under constant conditions.

TEMPERATURE STABILITY

0.5°C/°C*

*See next page.

4.1 (CONT'D)

RADIATION INTENSITY COMPENSATION

±[3°C (5°F) + 0.2% of temperature reading] for a factor of 3 radiation intensity change.*

LINEARITY

±[5°C (9°F) ±0.5% of calibrated temperature span]

UNIT CONVERSION ACCURACY

±5°C, ±9°F

RESPONSE TIME CONSTANT

0.3 seconds, standard

Options: Adjustable rise time constant and adjustable decay time constant. See Section 9.4.1 for details.

4.2 CALIBRATION

METHOD

Prior to shipment, each Ratio-Scope® is calibrated for black/gray body, tungsten or other specified target materials and target conditions. The required frequency of recalibration to maintain satisfactory accuracy will depend on environmental conditions and the degree of accuracy required. Nominal calibration period of one year is recommended.

CALIBRATION ACCURACY

±[10°C (20°F) + 1% of temperature reading],* referenced against a black body at calibration points. Calibration to customer samples/standards is available for a nominal charge. Calibration can be supplied in either Celsius or Fahrenheit.

*Specifications are not applicable to VH (Very High) range.

4.3 SENSOR SYSTEM

DETECTOR

Specially selected Silicon Cell.

FILTERS

Narrow bands around wavelengths in the near infrared. Special filters, for customer specified applications, are available on request.

4.4 OPTICS

LENS

Standard: 85 mm fixed focus (1 m to infinity)

Optional: 85 mm adjustable focus
150 mm adjustable focus

See Sections 7.2.1 and 9.2 for other optional optical arrangements.

FIELD-OF-VIEW

View Angle: Adjustable from 1° to 5° (with 85 mm lens).

SECTION 5

OPERATING PROCEDURES

5.1 GENERAL

Description of all the controls and indicators and procedures for the use of the Ratio-Scope® are given in this section. Refer to Section 7 for functional description of the instrument.

5.2 DESCRIPTION OF CONTROLS

See Figure 5-1

EYEPIECE

The digital display readout and the target are viewed through the eyepiece. The target can be seen through the eyepiece in the upper portion of the view and the digital display can be seen in the lower portion. The eyepiece should be adjusted to match the user's eye to obtain a clear image of the display.

OBJECT LENS

The object lens focuses the light from the target onto the plane of the Field-of-View Iris.

See Section 9.1 for description of controls on optional adjustable lenses.

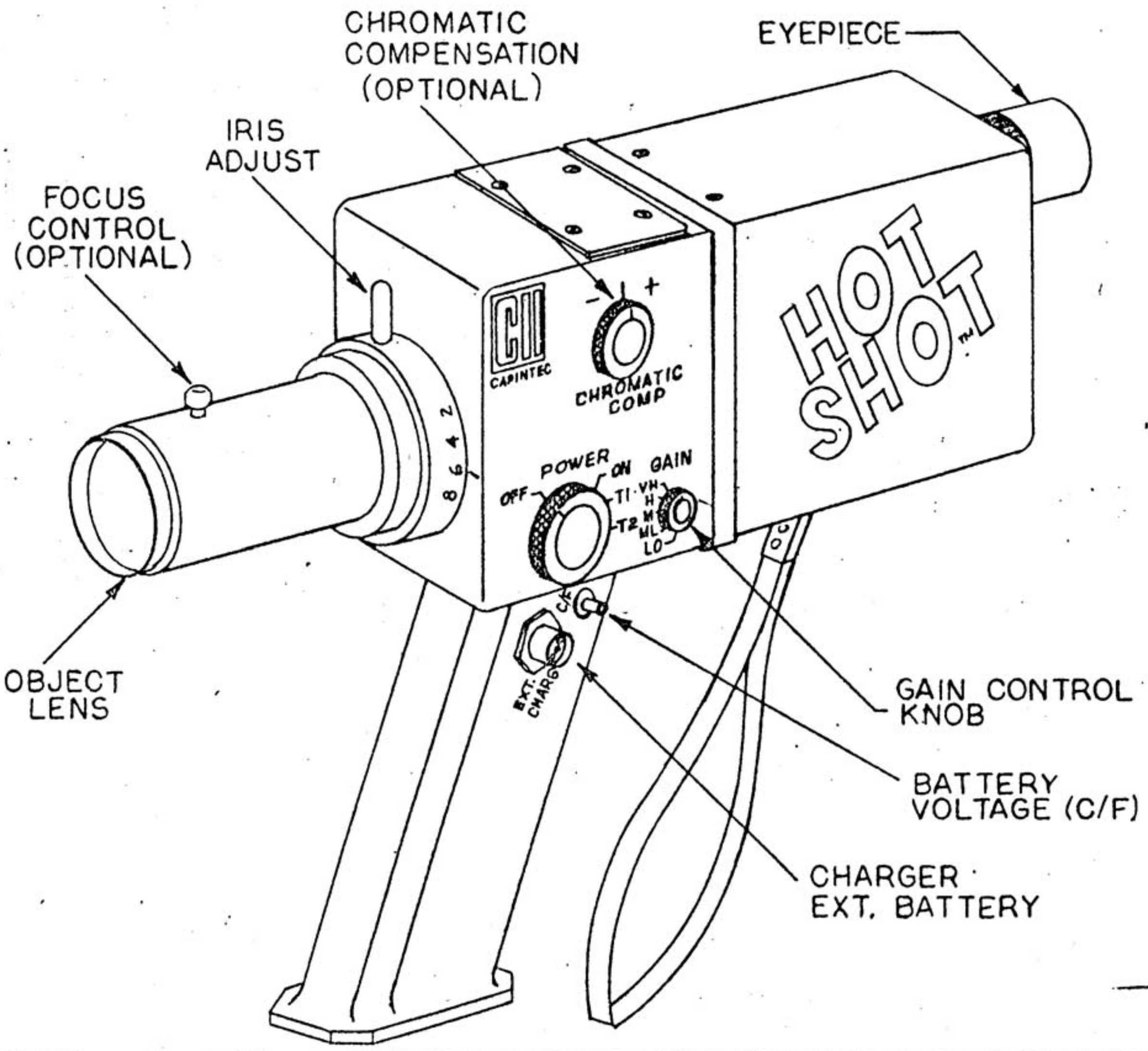
FIELD-OF-VIEW IRIS

Selects the portion of the target from which the temperature is to be determined.

The Iris control is marked: 2,4,6,8, and indicates approximate diameter in mm of the Iris opening.

READOUT

The digital display can be seen by sighting through the eyepiece.



CHROMATIC COMPENSATION (OPTIONAL)
EYEPIECE
IRIS ADJUST
FOCUS CONTROL (OPTIONAL)
CII
CAPINTEC
CHROMATIC COMP
HOT SHOT
POWER
OFF
ON
T1
T2
GAIN
VH
H
M
ML
LO
EXT. CHARG
OBJECT LENS
GAIN CONTROL KNOB
BATTERY VOLTAGE (C/F)
CHARGER EXT. BATTERY

Figure 5-1

5.2 (CONT'D)

Reading in degrees Celsius; standard.
Reading in degrees Fahrenheit; optional.
Reading in degrees Kelvin; optional.

The unit is indicated on the readout.

Dual Scale Option:

With this option, readings can be made in both °C and °F. Pressing and releasing the Voltage, C/F button will change the reading from °C to °F (or vice-versa); pressing and releasing it again will return the reading to the original scale.

Operator assist messages are also displayed on the readout.

GAIN CONTROL KNOB

This knob controls the gain of the amplifier according to the amount of radiation detected by the optical system. The knob has five discrete positions: Low Gain (LO), Medium Low (ML), Medium (M), High (H), and Very High (VH).

UNDERFLOW AND OVERFLOW (UFL, OFL) MESSAGES

If there is insufficient radiation being detected, UFL (underflow) will appear on the readout display; if there is too much radiation being detected, OFL (overflow) will appear on the readout display.

POWER SWITCH (OFF/ON/T1/T2)

When this switch is in the ON position, the necessary voltage is supplied to the circuitry.

When the switch is in the TEST position(s) T1 (and optional T2), the Internal Test Lamp is turned on.

Turn to OFF position while not in use to prolong battery life.

5.2 (CONT'D)

EXTERNAL BATTERY CHARGER

This receptacle is used when charging the internal battery which provides power to the circuitry. The instrument can be used while the battery is being charged.

This receptacle is also used when operating on the External Booster Battery or "panic" battery.

VOLTAGE. C/F PUSH BUTTON

While this button is pressed, the battery voltage will be displayed on the readout.

NOTE: The unit (volts) is indicated by the symbol °

This push button is also used to switch the unit from °C to °F and vice-versa (optional).

5.3 OPERATION

Hold the Ratio-Scope® so as to view the target at the most direct angle possible (i.e., perpendicular to the target's surface). It should be as close to the target as possible, while avoiding excessive heating.

The Ratio-Scope® should be used away from any source of stray infrared radiation (e.g., sunlight) including reflected or refracted radiation. If this is not possible, the object lens and the target should be shielded from such radiation. In other words, the radiation seen by the object lens should only be direct radiation from the target.

Splashing of oil or other contaminants on the lens should be avoided. See Section 8 for details of maintenance of the object lens.

5.3.1 PRE-MEASUREMENT PROCEDURE

Before operation, check the proper functioning of the Ratio-Scope®:

Step 1) Turn the Power Switch to the ON position and allow about 30 seconds for warm-up. Cover the lens by hand and look through the eyepiece. UFL°C or UFL°F should be displayed on the lower part of the view. If there is no display or if the display is very unstable, the internal battery has been drained and does not have enough charge for proper operation of the instrument. In this case, the Ratio-Scope® must be operated with the battery charger and ac power or with the "Panic" Battery Pack (optional) or with the External Booster Battery (optional).

Step 2) Push and hold VOLTAGE push button on the handle. If the reading is below 10 volts (10.0), the remaining life of the battery is less than one-half hour. If longer usage is anticipated the instrument must be operated with the battery charger and ac power, or with the "Panic" Battery Pack (optional) or with the External Booster Battery (optional).

Step 3) Select Test position(s) T1 (and T2--the second Test position is optional). Cover the lens by hand. Ascertain that the proper temperature readout is obtained. The correct temperature(s) is indicated on the body of the Ratio-Scope®.

CAUTION

The battery drains quickly when the test is being performed. Therefore, do not leave switch on Test longer than necessary.

Step 4) Return Power Switch to ON position.

5.3.2 OPTICAL ADJUSTMENTS

Step 1) Adjust the eyepiece until the digital display is in sharp focus. Alternatively, set the object lens at infinity (for lenses with adjustable controls only) and point the instrument at a distant object. Adjust the eyepiece until the distant object is in sharp focus.

Step 2) For lenses with adjustable controls:

Set the f-stop of the object lens to the widest opening, i.e., the smallest f-stop number.

Adjust the Focus Control until a sharp image of the target surface is obtained. The exact, sharp focus of the system is not critical for proper operation.

Step 3) If it is desired to measure the temperature of only a portion of the target, the Field-Of-View Iris should be adjusted so that only the portion of interest can be seen. If there are no such restrictions on target size, set the Field-Of-View Iris to its widest opening. If the target does not fill the entire Field-Of-View, make sure that the target is in the center of the Field-Of-View. See Appendix II for detailed discussion of setting the Field-Of-View Iris.

5.3.3 CONTROL ADJUSTMENTS

Step 1) Turn Gain Control Knob to H (High). (VH for very small, distant or low temperature target.)

Step 2) Turn Power Switch to ON position. Aim Ratio-Scope® at the target.

Step 3) Adjust the Gain Control Knob until OFL (overflow) message disappears from the read-out display and the target temperature is displayed.

A higher gain setting will be needed when measuring the temperature of a low temperature target or a small target or a distant target.

5.3.3 (CONT'D)

Step 4) For lenses with adjustable controls:

If OFL is still displayed after the Gain Control-Knob is turned to Low

a) Return Gain Control Knob to VH.

b) Reduce lens opening by changing f-stop 2 or 3 stops.

c) Repeat steps 3 and 4 until OFL message disappears.

Step 5) Adjust Time Control Constant Knobs (optional) for desired Rise Time and desired Decay Time.

5.3.4 MEASUREMENT

It is recommended that the Ratio-Scope® 5 be mounted on a tripod or unipod when sighting a small or distant target. In general, use of a tripod is recommended if one wishes to get the most accurate results possible.

Step 1) The Ratio-Scope® 5 is now properly set up and adjusted to accurately measure the temperature of the target.

Step 2) If display blanks out, the voltage is less than about 9.8 V and one of the auxiliary methods of power supply described in 5.3.1 must be used.

Step 3) Periodically check to ascertain that neither OFL or UFL is displayed. If either message is displayed, readjust the Gain Control Knob and/or f-stop control according to Section 5.3.3.

Step 4) Check readout display for OFL or UFL message whenever there is a significant change in the target's temperature.

Step 5) Periodically check to ascertain that no dust or oil has accumulated on the lens and that the desired portion of the target is properly selected by sighting through the eyepiece.

SECTION 6

CALIBRATION

6.1 GENERAL

Calibration procedures are described in this section.

6.2 FACTORY CALIBRATION

Prior to shipment, the Ratio-Scope® is calibrated at the factory. Calibration for black body (or gray body) radiation or calibration for tungsten is standard. Calibration for a target material other than above may be provided as an option.

A minimum of two known termperatures within the range of interest, preferably one near the lower end of the range (about 20% of calibrated range span) and one at the higher end (about 80% of calibrated range span) will be required to set up the calibration of the instrument.

Although temperature readings outside the calibrated range may be obtained, the accuracy may be reduced (or may not be valid) outside of the specified range.

6.3 CALIBRATION PROCEDURE

The ROS 5 may be calibrated by a user in the field against a known temperature source. If feasible, and necessary, the Ratio-Scope® should be calibrated against the actual target. If this is not possible, it can be calibrated against a source with emission characteristics similar to those of the actual target. In order to calibrate the instrument, it is necessary to know fairly accurately the temperature of the source (target) near the upper and lower limits of the temperature range of interest.

It is recommended that the instrument be calibrated under conditions simulating normal usage.

6.3.1 PREPARATION FOR FIELD CALIBRATION

The calibration setting potentiometers are not accessible from outside of the case. Use of the Ratio-Scope® with-

7.2.1 (CONT'D)

made using the new lens. Make sure that the portion of the target being viewed is the same for both measurements. If necessary, recalibrate the instrument according to the procedure given in Section 6.

Special object lens arrangements for particular applications may be supplied by Capintec Instruments according to the user's special requirements.

The image on the plane of the Field-of-View Iris may be observed through a telescope. The telescope consists of an eyepiece and a telescope object lens. A mirror and a beam splitter are used to deflect the path of the light.

The majority of the light which passed through the Field-of-View Iris is directed to the end of the light diffuser. The purpose of the light diffuser is to illuminate the optical sensors uniformly. The diffuser consists of an optical glass cylinder of the proper length. Each end of the cylinder is roughed to obtain scattering of light.

7.2.2 SENSORS

Two optical filters are attached to the end of the light diffuser cylinder. The filters select light in narrow bands around the two specially selected wavelengths.

The selected portion of light will be detected by the optical sensors. Silicon cells, specially selected for this application, are used as the optical sensors for the Ratio-Scope®. These cells exhibit exceptionally low noise levels and they are extremely stable.

The temperature of the silicon cell-optical filter assembly is stabilized by a temperature regulation circuit (optional: selectable only with External Booster Battery option). The temperature of the sensor assembly is kept at approximately 40°C (100°F).

7.3 CONTROL CIRCUITRY

The circuits of the Ratio-Scope® are designed based on the most recently available reliable components: MOSFET, JFET, low power precision operational amplifier, CMOS, cermet and metal film resistors, etc.

7.3 (CONT'D)

All the critical components are carefully selected for this application. Therefore, replacement with the same type components may not result in the proper functioning of the instrument.

Extreme care must be exercised when handling some of the components to protect them from damage due to static charge or induced potential on tools or hands. Follow the general procedure for handling non-protected MOS circuits.

For ease of assembly and service, the modular (or sub-assembly) concept is used. The replaceable modules are: Power Supply and Logic Board; Analog Circuit Board; Handle (Battery Assembly); Display Board and other sub-assemblies.

7.3.1 POWER SUPPLY AND LOGIC BOARD

A precision voltage regulator is used to produce a stable positive supply. Negative voltage is generated by the switching voltage doubler technique and stable negative voltage is obtained by means of an inverting voltage follower.

A 5 volt power supply for the digital display is also assembled on the same board.

All the time sequenced logics necessary to carry out the calculation of the intensity ratio at the selected wavelengths and to control the auxiliary circuits are generated in this board.

The time base of the circuitry is synchronized with the frequency of the ADC oscillator in order to reduce noise resulting from the oscillator. The time base operation frequency of the Ratio-Scope® is approximately 190 Hz, i.e., sampling of signals from the two detectors are switched every 5.3 ms. The frequency is selected so that the interference from a commercial power line will be averaged out without observable effects of beat frequency on the display reading.