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LASER MEASUREMENT SYSTEM
5526A
OPERATOR'S HANDBOOK

SERIAL PREFIX

This handbook applies to Hewlett-Packard
Model 5526A Laser Measurement System

INCLUDING

Laser Head Unit
Model Number 5500C

Laser Display Unit
Model Number 5505A

All serial prefixes
unless otherwise noted
with a change sheet.

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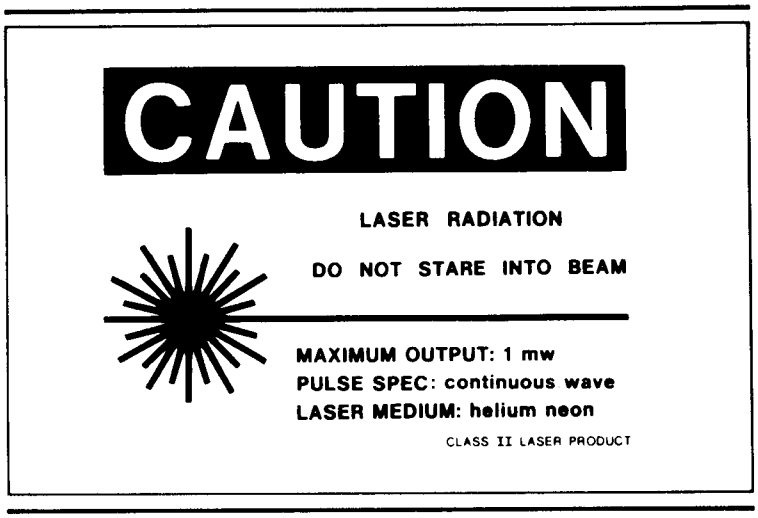
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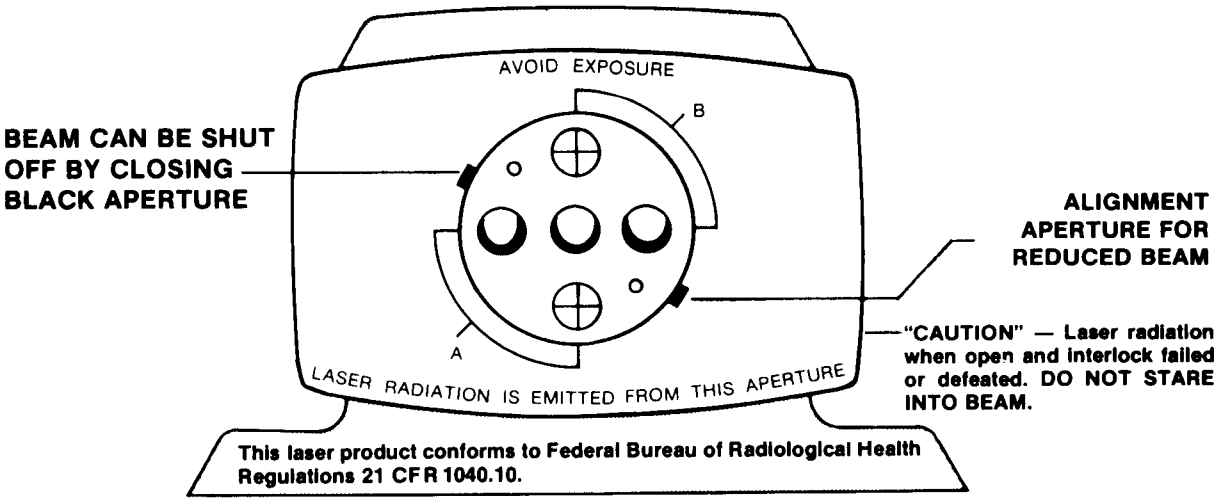
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SAFETY PRECAUTIONS

This is a Safety Class I system. This system has been designed and tested according to IEC Publication 348, "Safety Requirements for Electronic Measuring Apparatus". This product is also a Class II Laser Product conforming to Federal Bureau of Radiological Health Regulations 21 CFR 1040.10.





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SERVICE

Although this system has been designed in accordance with international safety standards, this manual contains information, cautions, and warnings which must be followed to ensure safe operation and to retain the system in safe condition. **Removal of the cover and subsequent service or adjustments should be performed only by qualified service personnel.**

WARNING

HIGH VOLTAGES ARE GENERATED WITHIN THE LASER HOUSING. THE COVER OF THE MODEL 5500C LASER IS PROVIDED WITH AN INTERLOCK TO PREVENT ACCIDENTAL ACCESS TO VOLTAGES. FOR SAFETY, THERE ARE NO HIGH VOLTAGES ON THE INTER-CONNECTING CABLE.

CAUTION

Any adjustment, maintenance, and repair of an opened instrument under voltage should be avoided as much as possible and, when inevitable, should be carried out only by a skilled person who is aware of the hazard involved.

Capacitors inside the instruments may still be charged even if the instruments have been disconnected from their source of supply.

Whenever it is likely that the protection has been impaired, the system must be made inoperative and be secured against any unintended operation.

Use of controls or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.

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INTRODUCTION

This handbook tells how to use the 5500C Laser Head and the 5505A Laser Display. These two units require one or more options (separate items) to make a complete Laser Measurement System.

CAPABILITIES OF LASER MEASUREMENT SYSTEM WITH OPTIONS

With available options the Laser Measurement System can be used to measure:

- Distance
- Angle (Pitch and Yaw)
- Flatness
- Straightness
- Squareness

The capabilities of a particular system depend on the options selected and supplied with the system. The details of installation, set-up, alignment and operation depend on the particular system and its options. So a separate manual supplement for each option describes details of installation, set-up, alignment and operation.

This basic manual describes only the system operating features that are common to system operation with most options.

5526A LASER MEASUREMENT SYSTEM PUBLICATIONS

The 5526A Laser Measurement System is completely described in the 5526A Service Manual. A listing of all publications about the Laser Measurement System is available from:

HEWLETT-PACKARD
5301 Stevens Creek Boulevard
Santa Clara, California 95050
United States of America
Attention: Laser Publications

LASER MEASUREMENT SYSTEM DESCRIPTION

The laser head projects a small round beam of intense light to an interferometer. The interferometer is an optical device that splits the laser output beam into two beams. The two beams are sent to two different reflectors which return both beams to the interferometer where the two beams are re-combined and go back to the laser head. In the laser head the two returned beams are compared for any change in the distance the beams travel. If the path length (travel distance) of either or both beams change, the change is measured and displayed by the system. This is the basic capability of the laser measurement system.

Refer to the Laser Block Diagram

A coherent light beam is produced in a helium-neon gas laser. A cylindrical permanent magnet around the cavity causes the laser to oscillate at two slightly different frequencies. This is Zeeman splitting. The two components, F1 and F2 (frequency one and frequency two) are distinguishable by their opposite circular polarizations.

From the laser tube the F1 and F2 beams pass through optical glass quarter-wave and half-wave plates which change the polarizations of F1 and F2 to linear vertical and linear horizontal. The linearly polarized beam is expanded in a collimating telescope, after which most of the beam is transmitted through a 45° main beam splitter and out of the laser head.

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A small part of the main beam is reflected 90° from its original path by the main beam splitter to the Lock and Reference polarizing beam splitter which splits the beam approximately 80% F1 to 20% F2 components in one direction and the opposite percentages in the other direction. The Lock and Reference polarizer-splitter changes the polarization of both F1 and F2 enough so that three signals can be detected:

1. F1 80%
2. F2 80%
3. F1—F2 for REFERENCE

The F1 and F2 80% signals are compared and used to provide the PZT error correcting signal through the regulator. The PZT error correcting signal keeps the F1 and F2 laser beam components equal strength which keeps the laser beam accurately centered on one wavelength.

The F1 and F2 beam out of the Laser Head is aimed at an interferometer which splits F1 and F2. Component F1 is in a fixed distance path and F2 is sent to a target which reflects F2 back to the interferometer. Relative motion between the interferometer and the reflector causes a shift in the returned frequency. The photodetector therefore sees a fringe frequency given by F1 - F2 ± ΔF.

The F1 - F2 ± ΔF signal that is returned from the external interferometer is compared in the calculator with the F1—F2 Reference signal. The difference ΔF is added to the fringe count accumulated in the register.

It is important to note that the Hewlett-Packard 5526A Laser Measurement System measures only *changes* in distance between the remote interferometer and reflector or, in other words, displacement. It does not measure distance between the interferometer and the target reflector directly.

Remote Control Module Description

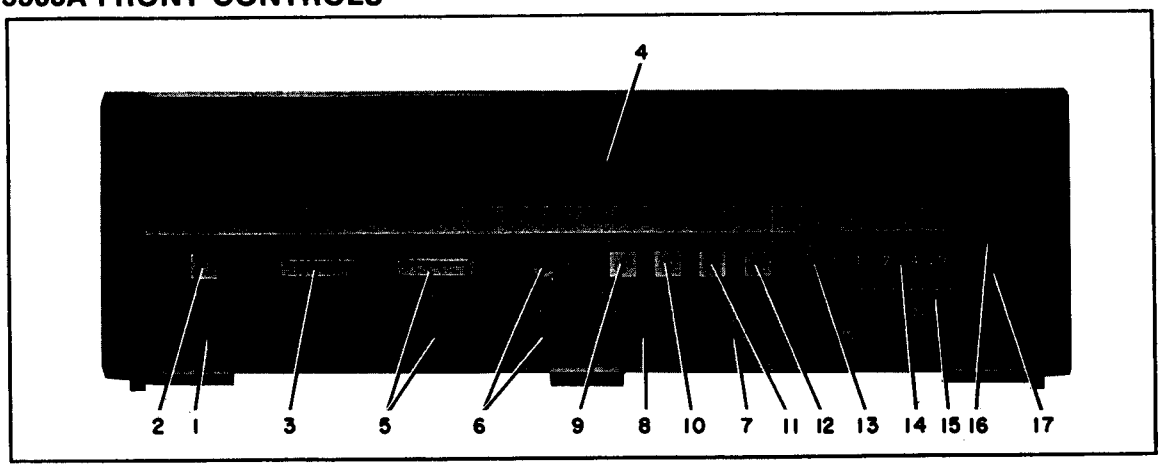
The Remote Control Module allows the user to remotely reset the 5505A Display. The module performs three functions:

1. Allows remote resetting of the 5505A.
2. Allows issuing of a print command.
3. Provides a remote Beam Alignment Meter.

PLANE MIRROR CONVERTER OPERATION

When using the Laser Measurement System with the Plane Mirror Converter 10581A, there is optical resolution doubling due to the two reflections that are inherent in the plane mirror principle. To correct the resolution, capacitors C32 and C34 on Analog board A1 in the 5505A Laser Display must be removed. Refer to the 5526A Service Manual for details.

5505A FRONT CONTROLS



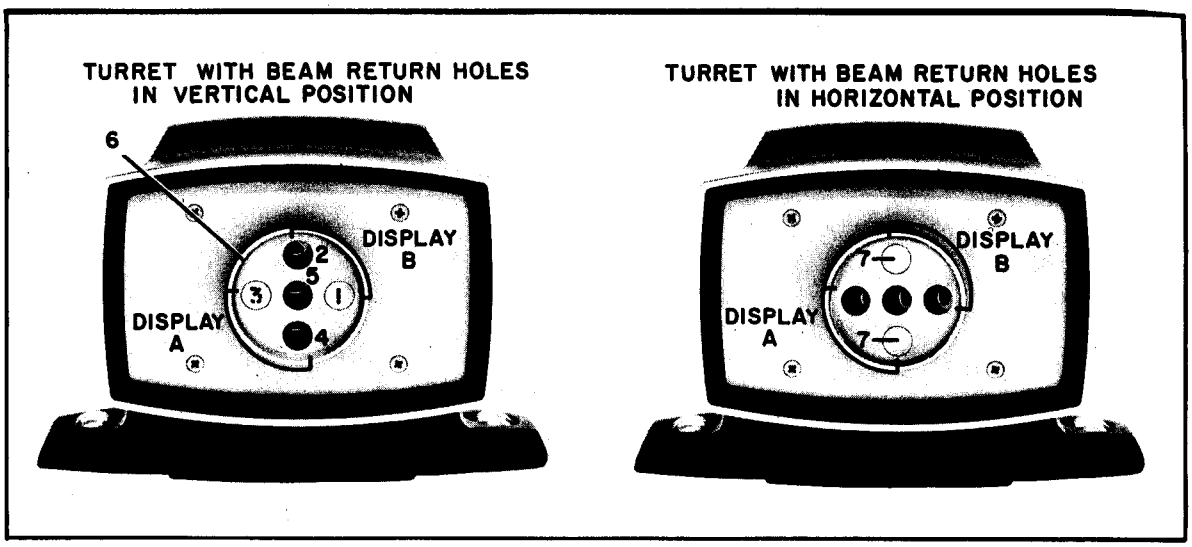
1. **SYSTEM POWER SWITCH:** In ON position provides primary power to system.
2. **RESET PUSHBUTTON:** Provides dual function as error indication and system reset button. Begins flashing when any of the following error conditions occur:
   a. Laser reflector has been moved faster than maximum slew rate.
   b. **BEAM ALIGNMENT** meter is in red range, indicating loss of reflected beam from misalignment, attenuation.
   c. **LASER TUNING** meter is in red range, indicating manual retuning is required.
   d. Laser beam was stopped.

   Pressing the RESET button resets the counters and display to zero so that measurements can begin. When the RESET button flashes for any of the above reasons, the display immediately reads out all zeros and the previous reference point is lost. Depressing the RESET button then defines a new reference point at the current position.
3. **BEAM ALIGNMENT METER:** Indicates signal strength of reflected beam through the return port. Alignment of the laser reflector should be such that meter reading is maximized in the green area. Beam power loss greater than 95% corresponds to red area of meter, and causes RESET button to flash.
4. **DISPLAY PANEL:** Contains 10 display tubes consisting of a ± sign and 9 numeral positions to indicate distance and velocity measurements. Also displays decimal points or commas as appropriate while indicating measurement in inches, millimeters, or quarter wavelengths. Decimal point and comma display tubes can be interchanged to accommodate English or Metric convention, as preferred.
5. **LASER TUNING METER AND TUNE SWITCH:** Meter indicates state of automatic laser tuning circuit. Green area in center represents proper tuning. Switch permits right or left meter needle movement by manual override of tuning circuit, and is used to return meter needle to the green area, if necessary. Use of switch alters the laser cavity length and therefore causes loss of any measurement being displayed. (RESET light will flash.)
6. **PRINTS—PLOTS/MIN AND PRINT SWITCHES:** Rotary switch selects rate of accessory printer or plotter, or enables sequential contact closures (available at the rear panel) for the rate selected. Toggle switch provides momentary contact closure each time placed to MANUAL position. TIMED position actuates PRINTS PLOTS/MIN selected.
7. **UNITS SWITCH:** Selects measurement units in **mm** (millimeters) **λ/4** (one-fourth wavelengths of light) or **in.** (inches) for display. May be used to show readout of the same measurement in all three units successively without loss of data. (Measurements displayed in quarter/wavelengths are not compensated for velocity of light in air.)
8. **DIRECTION SENSE SWITCH:** Defines directional movements of the Reflector or Interferometer in all measurement modes as evidenced by the "+" or "–" indicator. When switch is set to **F** (forward), movement of the reflector away from the Interferometer is defined as positive (+). When set to **R** (reverse), the same movement is defined as negative (-).
   MODE PUSHBUTTONS: One of four pushbuttons is lighted at any one time to indicate measurement mode. Modes can be changed by pressing any button during or after measurement, without loss of data. Commas and decimal points are placed automatically in accordance with mode.
9. **NORMAL PUSHBUTTON:** Selects normal display mode; instrument appears in this mode after each turn-on. Display is 5 digits to the right of the decimal in inches, or 4 digits in millimeters; overflows at 258 feet or 79 meters.
10. **SMOOTH PUSHBUTTON:** Useful in environments subject to vibration. Same as NORMAL mode except right-most digits of display are electronically filtered to show average position.

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5500C LASER FRONT PANEL



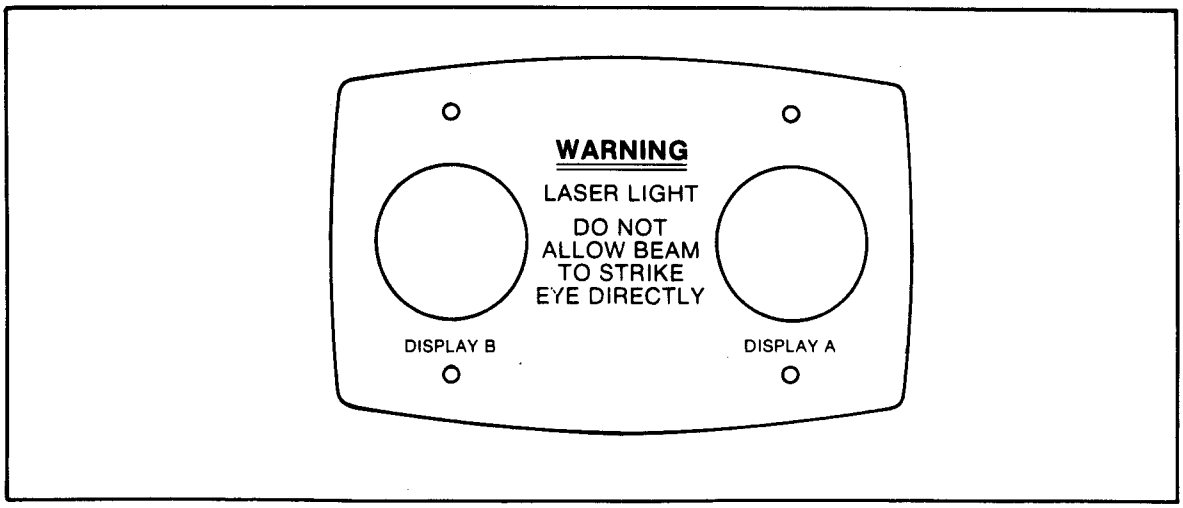
1., 2., 3., 4. **LASER BEAM RETURN HOLES:** The laser beam is returned to one or two of these four holes.

5. **LASER BEAM SOURCE HOLE:** The laser beam exits from this hole.

6. **LASER BEAM TURRET:** Rotatable turret for laser beam provides either horizontal or vertical orientation.

7. **BEAM TARGETS:** During alignment the arget area in the ring is used to see where the reflected laser beam is shining. Moving the turret will put a target in front of any beam return hole.

5500C LASER REAR PANEL



1. **DISPLAY UNIT A CABLE CONNECTOR**

2. **DISPLAY UNIT B CABLE CONNECTOR**

Remote Control Module Operation

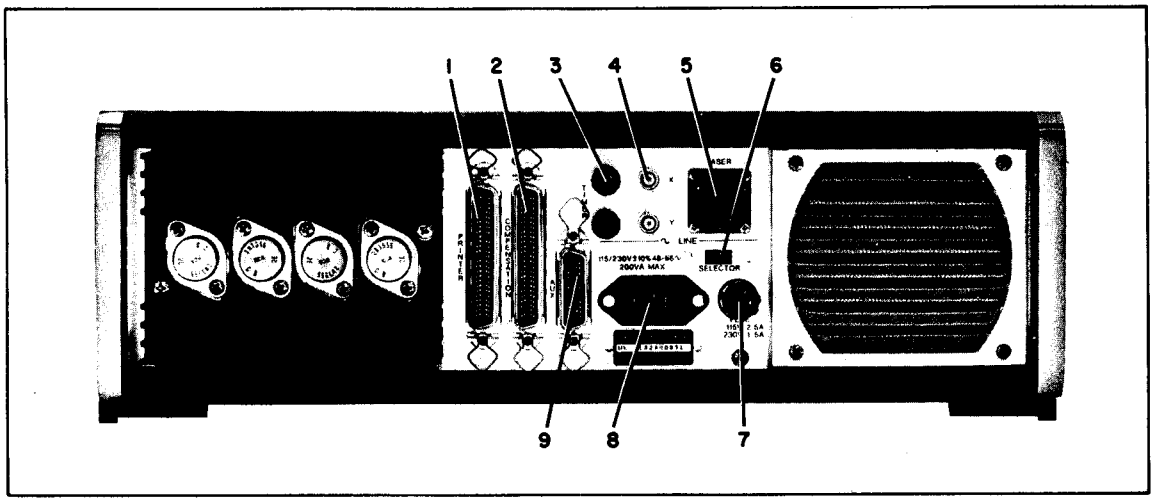
1. Press RESET switch to reset the 5505A Display. Performs the same function as the 5505A front panel RESET switch.

2. When the 5505A PRINT switch is set to MANUAL, pressing the PRINT switch on the Remote Control Module causes a print command to be issued from the rear panel connector on the 5505A.

3. The Beam Alignment meter on the Remote Control Module duplicates the meter function of the BEAM ALIGNMENT meter on the 5505A.

11. **X10 PUSHBUTTON:** Same as SMOOTH mode except display resolution is greater by an order of magnitude; decimal point is shifted one position to the left, displaying 6 digits to the right in inches, or 5 digits in millimeters. Overflows at 50 feet or 10 meters.
12. **VELOCITY PUSHBUTTON:** Indicates rate of reflector movement at up to maximum slew rate. Does not cause loss of distance data or reference point of previous modes.
13. **VELOCITY SWITCH:** Selects units per second (s position) or per minute (m position) in VELOCITY mode.
14. **COMPENSATION—PPM (Parts-per-million) THUMBWHEELS:** Number from compensation chart is entered to offset effects of temperature, humidity, and barometric pressure on velocity of light in air. Also accepts number to compensate for temperature of object measured.
15. **AIR COMPENSATION TABLE:** Abbreviated table used to derive gross compensation number within about 10 parts-per-million accuracy. **CHECKS 1 and 2 SWITCHES:** Perform self-checks of the counting and computing circuits. Number displayed should coincide with test number shown on AIR COMPENSATION TABLE, bottom line. Previous distance data or reference points are lost when using the CHECKS switches.
16. **CHECKS 1 SWITCH:** Causes the number +6230231 to be read out in inches or +15824787 in millimeters. Causes +999 followed by the 4-place number on the thumbwheels to be displayed when the UNITS switch is at λ/4. (If the DIRECTION SENSE switch is set to **R**, numbers are preceded by "-".)
17. **CHECKS 2 SWITCH:** Causes the counters to reverse and the opposite polarity sign to be displayed.

5505A REAR CONNECTORS



1. **PRINTER CONNECTOR J2:** Provides BCD output of number being displayed. Used in conjunction with accessory HP Model 5055A Digital Recorder.
2. **COMPENSATION CONNECTOR J3:** Permits input of number required to compensate for atmospheric variations and workpiece temperature. Used with accessory HP Model 5510A Compensator.
3. **TIMER JACKS:** Provides floating contact closure for use in stepping a numerically controlled machine, for example. Rate governed by front panel **PRINTS-PLOTS/MIN** switch.
4. **RECORDER CONNECTORS:** Provides error plotting output for driving accessory Model 7035A X-Y Recorder, or equivalent, to graphically display machine positioning errors (X upper, Y lower BNC).
5. **LASER CONNECTOR J1:** Provides interconnection with LASER using 15-foot cable provided.
6. **115V—230V SELECTOR SWITCH:** Permits selection of 115 or 230 Vac to match primary power source. **Caution: Put this switch in the correct position before connecting power cable.**
7. **FUSE RECEPTABLE:** Contains 2.5A fuse for 115V operation or 1.5A fuse for 230V operation.
8. **115V—230V AC RECEPTACLE:** Provides connection (with power cord supplied) to either 115V or 230V primary source.
9. **AUX CONNECTOR J4:** Provides several status signal outputs and control signal inputs for remote programming.

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DUAL MEASUREMENT

A 5500C Laser Head can operate with either one or two 5505A Laser Display units. With two 5505A units connected, two separate, simultaneous measurements may be made requiring two interferometers. The return-beam apertures (one pair for each channel) are labeled A and B and are associated with the A and B connectors respectively at the 5500C rear panel.

SYSTEM INTERCONNECTION

Use the following procedure when you hook up the laser system for the first time.

This procedure will familiarize new operators and give a confidence check for the laser measurement system. With the system hooked up for operation as explained in the following paragraph, perform the checkout procedure in order as follows:

1. Determine whether 115 or 230 Vac is to be used for primary power.
2. On rear panel of the DISPLAY use small screwdriver to set SELECTOR slide switch so that voltage shown matches primary power source (115 volts or 230 volts AC).
3. Check that the FUSE receptacle contains the appropriate fuse (as labeled) to match the power source.
4. Install 15-foot interconnection cable supplied with the system between the laser and the display. At the laser end, connect the cable to the DISPLAY A connector.

CAUTION

To avoid possible damage to the display circuits:

A. Always make certain that power is not applied when installing the interconnecting cable.

B. Do not remove the cable with power applied.

5. Check that power ON switch on display front panel is in the off (down) position. Connect the 3-pronged power cord supplied with the system to the ac receptacle on the display rear panel and connect the other end to the primary power outlet.
6. On display front panel, set system power switch located on left side of unit to the ON (up) position.

Remote Control Module Installation

1. Disconnect power to the 5505A Laser Display.
2. Connect the module connector to the AUX connector J4 on the 5505A.

PRELIMINARY BENCH CHECKOUT

1. With power applied, observe that the display panel numbers light, that the NORMAL pushbutton lights, and that the RESET light comes on in about 3 to 5 seconds and begins flashing. Depress the SMOOTH, X10, VELOCITY, and NORMAL pushbuttons in turn and observe that each lights up individually.
2. Observe that the laser is on, as shown by a red laser beam shining from the middle hole of the laser turret. Never look into the laser beam turret hole. If the reflected spot is not obvious, use a piece of paper or your hand to break the beam on the display. Check that the LASER TUNING meter is in the green area. Open the compensation door and press button CHECKS 1. Set the UNITS switch to "in" and observe that the number +6230230 is displayed. Set the UNITS switch to "mm" and observe that +15824785 is displayed. Set the UNITS switch to $\lambda 4$ (quarter/wavelengths) and observe that +999 followed by the compensation switches through the entire number system, if desired, to observe that the display changes on each corresponding number change. Return the thumbwheels to the original number as entered from the appropriate compensation table (725.0 is a nominal setting). Press CHECKS 2 button and observe after several seconds that the display changes polarity sign. Also, change the setting of the DIRECTION SENSE switch and note that the polarity sign changes.
3. Set the PRINT switch to TIMED, rotate the PRINTS-PLOTS/MIN switch to 6 and listen for a relay click every 10 seconds. Rotate the switch to 60 and listen for a click each second. Press the PRINT switch toward the MANUAL position and listen for a click upon releasing the switch.

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The preceding checkout procedure tests everything in the 5526A Laser Measurement System that can be checked without one of the system-completing options.

COMPENSATION

The absolute accuracy of the laser depends directly on the compensation factor entered for the velocity of light in air and the temperature of the object being measured. Thumbwheel switches behind a hinged door on the right side of the laser display are used to correct for two sources of measurement error: (1) the effect of ambient temperature, pressure, and humidity on the laser wavelength, and (2) changes in the size of the measured part with temperature.

5510A AUTOMATIC COMPENSATOR

The optional 5510A automatic compensator can be used to eliminate compensation problems.

WAVELENGTH COMPENSATION

The wavelength of light in air (used as the standard in the distance measurement) is slightly affected by air temperature, pressure, and relative humidity. Air that is less dense (for example, low pressure, high temperature air) results in a higher velocity of light, and thus, a longer laser wavelength. The thumbwheel switches on the display unit allow the user to adjust for these variations in wavelength.

The distance shown on the laser display at any time is equal to the product of the laser light beam wavelength (in units of inches or millimeters) multiplied by the number of wavelengths of motion counted since the RESET button was last pressed. In practice, this multiplying operation is done in two steps. First, the number of wavelengths counted is multiplied by the ratio of the wavelength in air to the wavelength in a vacuum, and this result is then multiplied by the vacuum wavelength of the laser light (in appropriate units). That is:

$$\text{distance} = \text{wavelengths of motion} \times \frac{\text{air wavelength}}{\text{vacuum wavelength}} \times \text{vacuum wavelengths (in appropriate units)}$$

The vacuum wavelength is a constant which is "hard-wired" into the instrument calculator assembly. The ratio of air wavelength to vacuum wavelength is a number always slightly less than 1 which depends on ambient conditions. As an example, for air temperature = 77°F, air pressure = 30.00 inches Hg, and relative humidity = 50%, this ratio is equal to 0.9997329. For the operating environment specified for the laser, no change will ever occur in the first three digits of the ratio. These digits (i.e., 0.999) are therefore fixed within the instrument. The last four digits are dialed in by the user on the thumbwheel switches.

USE OF COMPENSATION CHARTS

The numbers to be entered on the thumbwheels can be found in the Laser Compensation Factor Handbook. The compensation factor handbook is supplied with each Laser Measurement System.

SENSOR CONSIDERATIONS

To use the charts, ambient temperature, pressure, and (if desired) relative humidity must be measured. The sensing devices should be placed so they measure the environment close to the measured path. The accuracy with which the compensation number is determined (and thus the accuracy of the distance measurement) can be no better than the accuracy of the ambient condition sensors, so they should be chosen with some care. As a guide, it can be stated that an error of approximately 1 part-per-million will be incurred in the distance measurement for each error of 2°F in ambient temperature, 0.1 inch Hg in ambient pressure, and 30% in relative humidity.

It should be emphasized that the ambient pressure used in determining the compensation number must be *absolute* barometric pressure and not the usual published relative barometric pressure, which is usually absolute pressure "corrected to sea level". That is, barometric pressure as usually given is the absolute pressure which would exist in a given area if the same weather conditions prevailed and if that area were at sea level rather than its particular altitude. For example, weather reports in Denver, Colorado, might give the barometric pressure on a certain day as 30.00 inches Hg. But the absolute pressure there on that same day would be closer to 25 inches Hg because the altitude is about 5000 feet. To measure absolute pressure then, the user needs an absolute pressure indicator, which is equivalent to a barometer that has not been corrected at sea level. The HP 10560A Barometer indicates absolute barometric pressure. When no pressure indicator is readily available, a reasonable approximation to absolute pressure can be found by decreasing the barometric pressure (obtained from the nearest weather station) 0.1 inches Hg for each 100 feet of altitude. *NOTE: The most common use for any local barometric pressure is the setting for aircraft altimeters which is a relative reading.*

PART TEMPERATURE COMPENSATION

In addition to light wavelength compensation, the measurement must be corrected for the temperature coefficient of material of the item being measured. Most materials expand with increases in temperature. If a part is measured at two different temperatures, two different size determinations will result, and the difference can easily be as great as a part in 10^4. There is thus a significant ambiguity about the "true" size of the part. To remove this ambiguity, a reference temperature must be established. The size of the part is then defined as the measured size when the part is at the reference temperature. A reference temperature of 68°F (20°C), will be used in this book.

EXPANSION COEFFICIENT

Ideally, all distance measurements with the laser would be done in a temperature controlled room held at exactly 68°F (20°C). Then all parts would be at their "true" size and the compensation number determined above could be used directly. Temperature controlled rooms are not always available, so some method of accurate measurement must be available for part temperatures other than 68°F. The best method is to change the effective laser wavelength by changing the compensation thumbwheels an amount just sufficient to correct for thermal expansion. To accomplish this, the coefficient of expansion and temperature of the measured part must be known. For example, assume a steel part is being measured (or a steel machine is being calibrated). The coefficient of expansion of ordinary steel is about 6.5 parts-per-million-per-degree Fahrenheit. Also, assume that part temperature has been measured and found to be 80°F, or 12°F above the reference temperature of 68°F. Then it is clear that the part is 6.5 ppm/°F = 78 parts-per-million larger in its present state than it would be at 68°F. Assume the part is precisely 1-inch long at 68°F. If we measured the part at 80°F, the display would indicate 1.000078 inch. But we want the display to indicate 1.000000 inch, i.e., the "true" size of the part. We can force the display to indicate the "true" number if we decrease the compensation number by 78 ppm from its strict air wavelength value. In effect, we thus compensate for the temperature of the part and measure it at its reference temperature size.

The compensation thumbwheels can be read as "parts-per-million" when the decimal point is placed between the third and fourth digits. Thus, to obtain part compensation, it is only necessary to calculate the expansion of the part (or machine) in parts per million, and subtract this number from the previously determined wavelength compensation number. (If the part temperature is below the reference temperature, the parts-per-million correction should be added instead of subtracted.) The formula to apply is:

Thumbwheel setting = wavelength compensation No.–(TP–68) x (expansion coefficient)

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where Tp is the part temperature in degrees Fahrenheit, and the expansion coefficient is expressed in ppm/°F. Example:

Air Temperature:	72°F
Absolute Pressure:	30.2 in. Hg
Relative Humidity:	50%
Part Temperature:	75°F
Part Expansion Coefficient:	6.5 ppm/°F
Reference Temperature:	68°F

a. From the table (50%) relative humidity) the wavelength number can be determined. Find 30.20 in. Hg along the left hand edge and move across to the 72°F column, reading 728.5.

b. The correction for part expansion is:

$$(75°F - 68°F) \times 6.5 \text{ ppm/°F} = 45.5 \text{ ppm}$$

Since part temperature is above 68°F, this number should be subtracted from the wavelength compensation number.

c. The resulting number is:

$$\begin{array}{r} 728.5 \\ -45.5 \\ \hline 683.0 \end{array}$$

d. Enter this number into the thumbwheel switches.

MANUAL CHANGES — BACKDATING

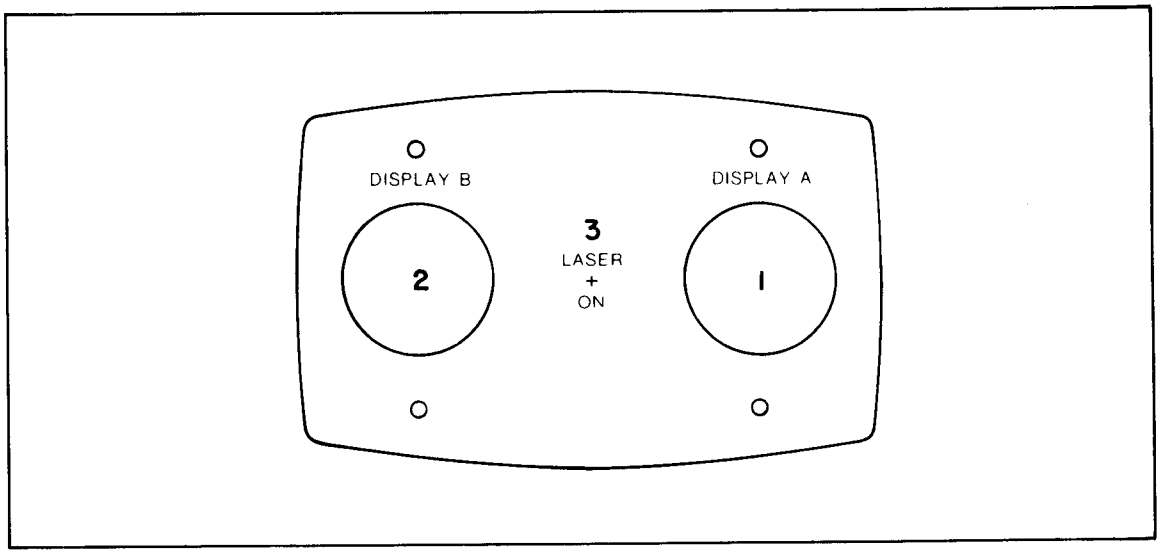
The table below identifies previous serial prefixes of units that differ electrically from those documented in this manual. If your unit has one of these prefixes, make the changes indicated.

Backdating Table

Serial Prefix	Make Changes to this Manual
5500C (1644), (1604)	Manual not affected by these changes
5500C (1544A), (1436A), (1224A)	CHANGE 1
5505A (1640A), (1624A), (1528A), (1512A), (1436A), (1312A)	Manual not affected by these changes
5505A (1132A)	CHANGE 2
5505A (2016A)	Manual not affected by these changes
5505A (Below 1948A)	CHANGE 3

CHANGE 1

Page 4, 5500C LASER REAR PANEL:
Substitute the following rear panel drawing:



1. **DISPLAY UNIT A CABLE CONNECTOR**
2. **DISPLAY UNIT B CABLE CONNECTOR**
3. **LASER ON INDICATOR**

CHANGE 2

Page 5, PRELIMINARY BENCH CHECKOUT, step 2:
After the 7th sentence, add the following Note:

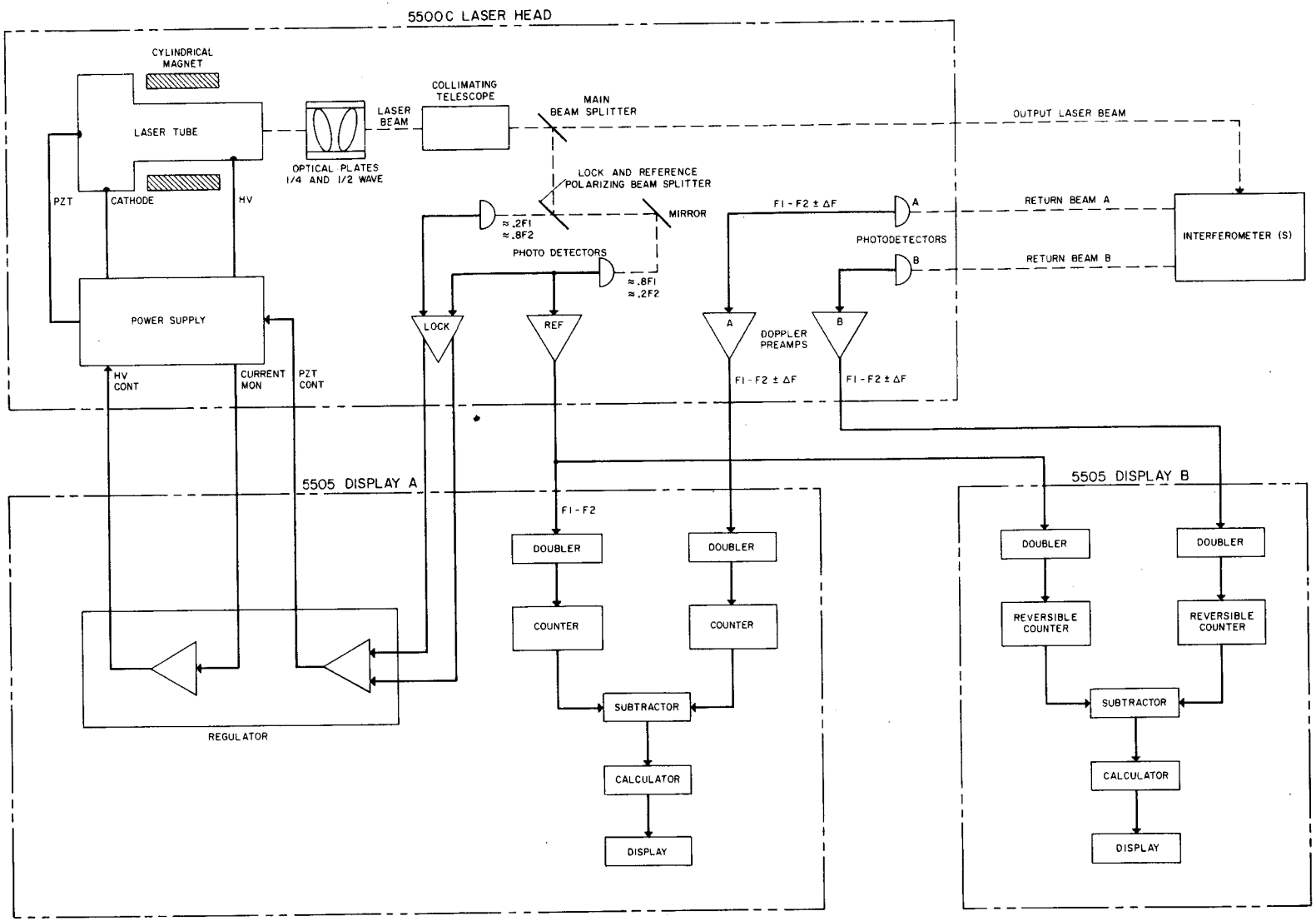
NOTE

If 5505A Laser Display has Serial No. 1132A00485 or below, the 4 numbers are slightly different and produce an indication of 6230231 when UNITS switch is at "in" or 15824787 with UNITS switch at "m".

CHANGE 3

For serial prefixes below 1948A, the Remote Control Module (HP Part No. 05505-60021) was not supplied as a standard item. Prior to 1948A, the Remote Control was available as Special Option K07-59995A.

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5526A Laser Measurement System
Block Diagram

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