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Laser Measuring System for Wire-Wrapped Frame Assemblies

J. G. Etzel and J. A. Munford

MARCH 1979

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771



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LASER MEASURING SYSTEM FOR WIRE-WRAPPED FRAME ASSEMBLIES

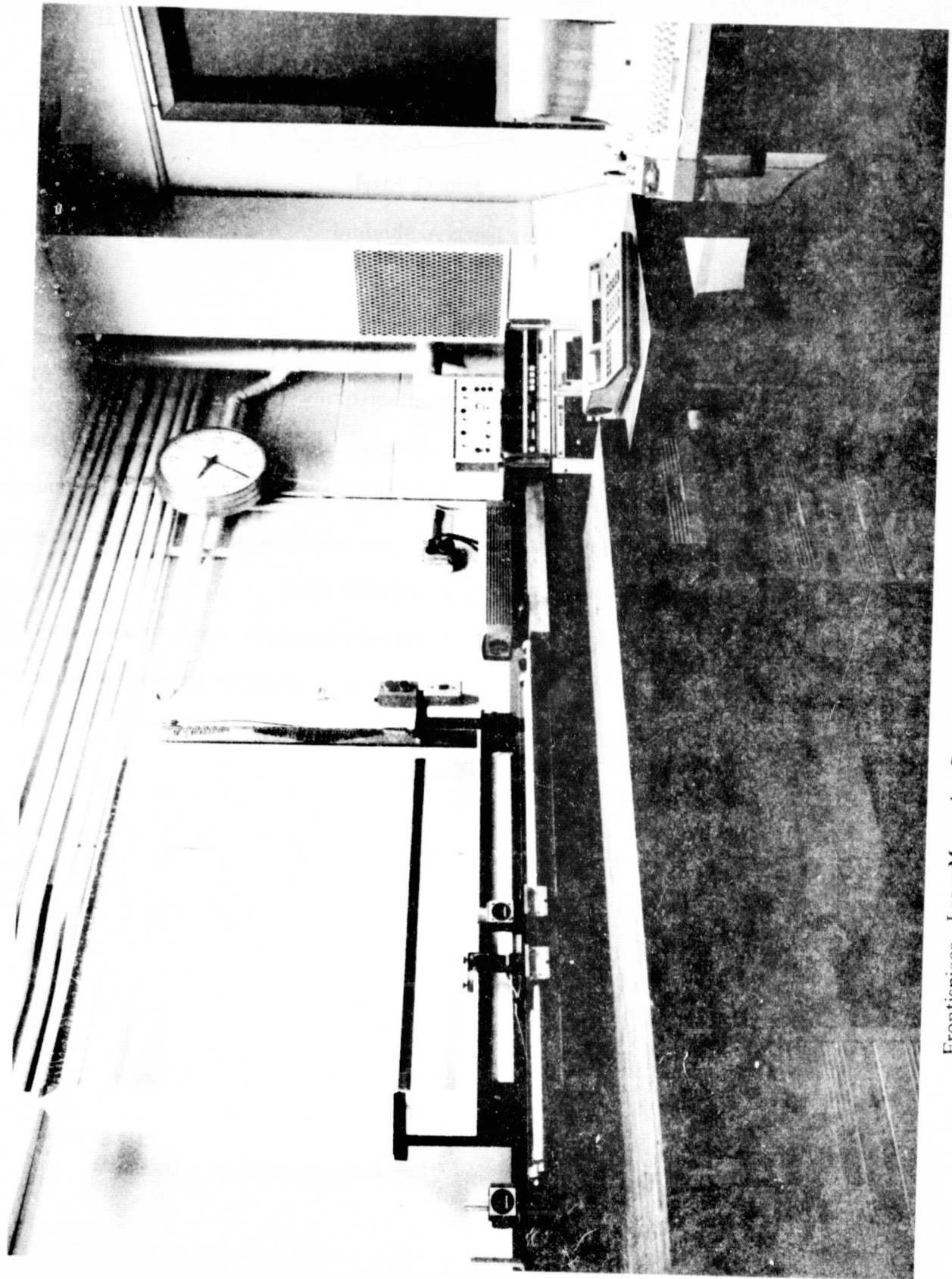
John G. Etzel

James A. Munford

ABSTRACT

The Laser Measuring System is designed to automatically measure and record the distances between small diameter wires on a wire-wrapped grid frame assembly to an accuracy of 0.00635 mm (0.00025 in.). The System utilizes a helium-neon gas laser beam as the measuring instrument with a remote interferometer and retroreflector, a light source and photo-detector to detect the wire positions, in conjunction with recording, display and printout units.

The Laser Measuring System can be utilized to perform precise automatic measurements for wire application machines or as an automatic feedback device for positioning wires and/or to adjust them for out of tolerance conditions.



Frontispiece. Laser Measuring System for Measuring Wire-Wrapped Frame Assemblies

LASER MEASURING SYSTEM FOR WIRE-WRAPPED FRAME ASSEMBLIES

INTRODUCTION

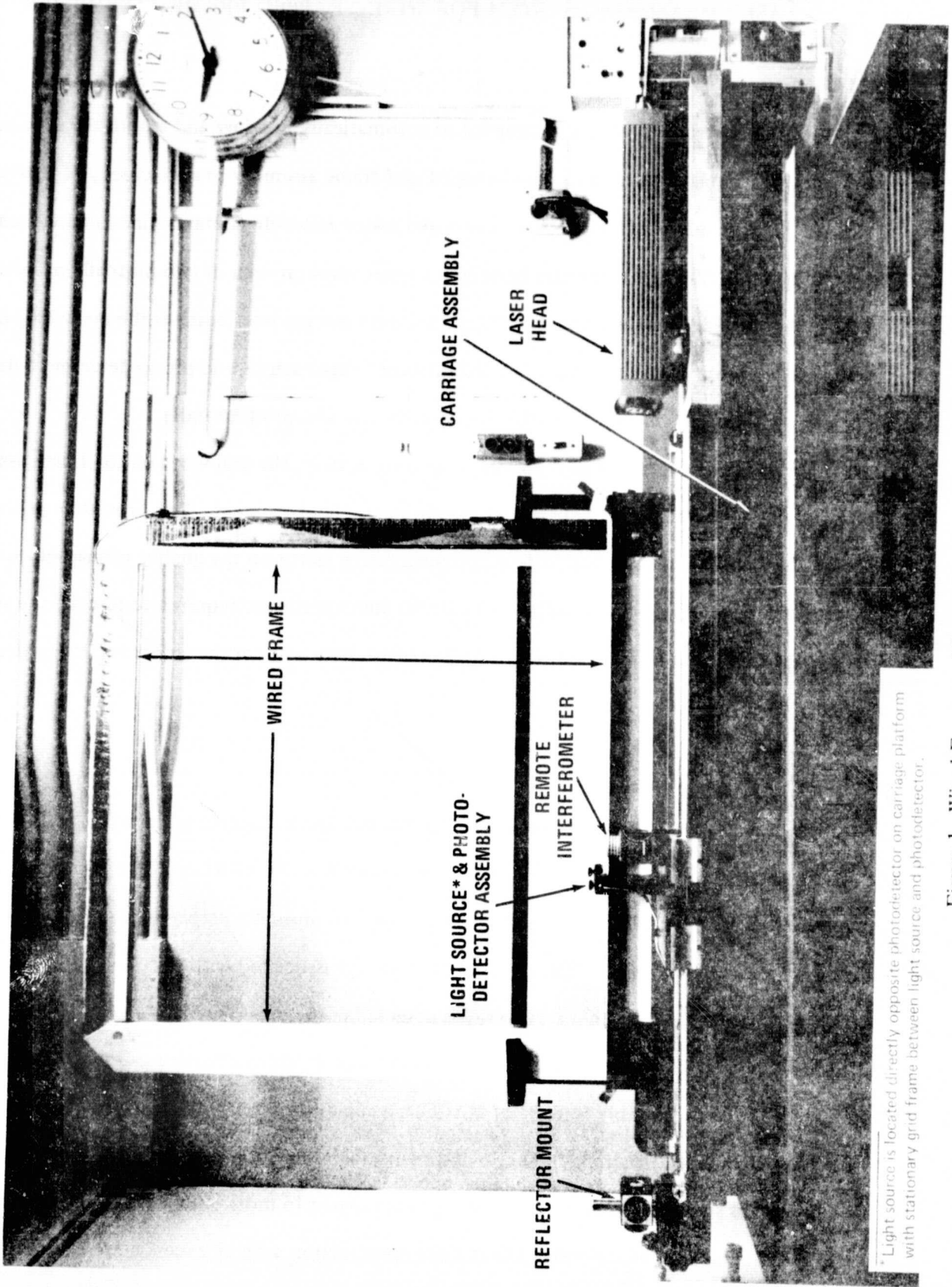
The Laser Measuring System is designed to automatically measure and record the distances between small diameter wires on a wire-wrapped grid frame assembly to an accuracy of 0.00635 mm (0.00025 inches), refer to Frontispiece. The wired frame assembly contains nine-hundred ninety-two 0.076 mm (0.003 inch) diameter beryllium copper wires on each of two mutually perpendicular planes. The System, Figures 1 and 2, utilizes a helium-neon gas laser beam as the measuring instrument with a remote interferometer and retroreflector, a light source and photo detector to detect the wire positions, in conjunction with recording, display and printout units.

Prior to the development of the Laser Measuring System, the grid wires on the frame assemblies were measured manually with a standard optical theodolite instrument. This procedure proved very tedious for the inspector as visual fatigue became a prime factor on the quality of inspection. Under the optical system of inspection, approximately 50 man-hours were required to inspect one frame assembly as compared to the one hour operation inspection time for the automatic Laser Measuring System.

APPLICATION

The basic component of the Gamma-Ray Telescope spark chamber is the wired grid frame assembly shown in Figure 3. The frame has a square opening, 81 by 81 cm (32 by 32 inch), with two planes of 992 parallel and evenly spaced wires on two mutually perpendicular planes. The two planes are separated by 4 mm. Each wire on the frame is associated with circuitry which records the current that is generated when a gamma ray is detected in the experiment. Refer to Figure 4, Spark Chamber X and Y Core Array, and Figure 5, Gamma-Ray Telescope Experiment.

The grid frame assembly is made of MACOR, a ceramic material selected for its low outgassing properties, high dielectric strength, excellent dimensional stability, high modulus of elasticity, good structural yield strength and ease of machining as compared to most other ceramic materials. The frame design, Figure 3, incorporates a four piece construction with all excess material removed to



*Light source is located directly opposite photodetector on carriage platform with stationary grid frame between light source and photodetector.

Figure 1. Wired Frame and Laser Carriage Assemblies

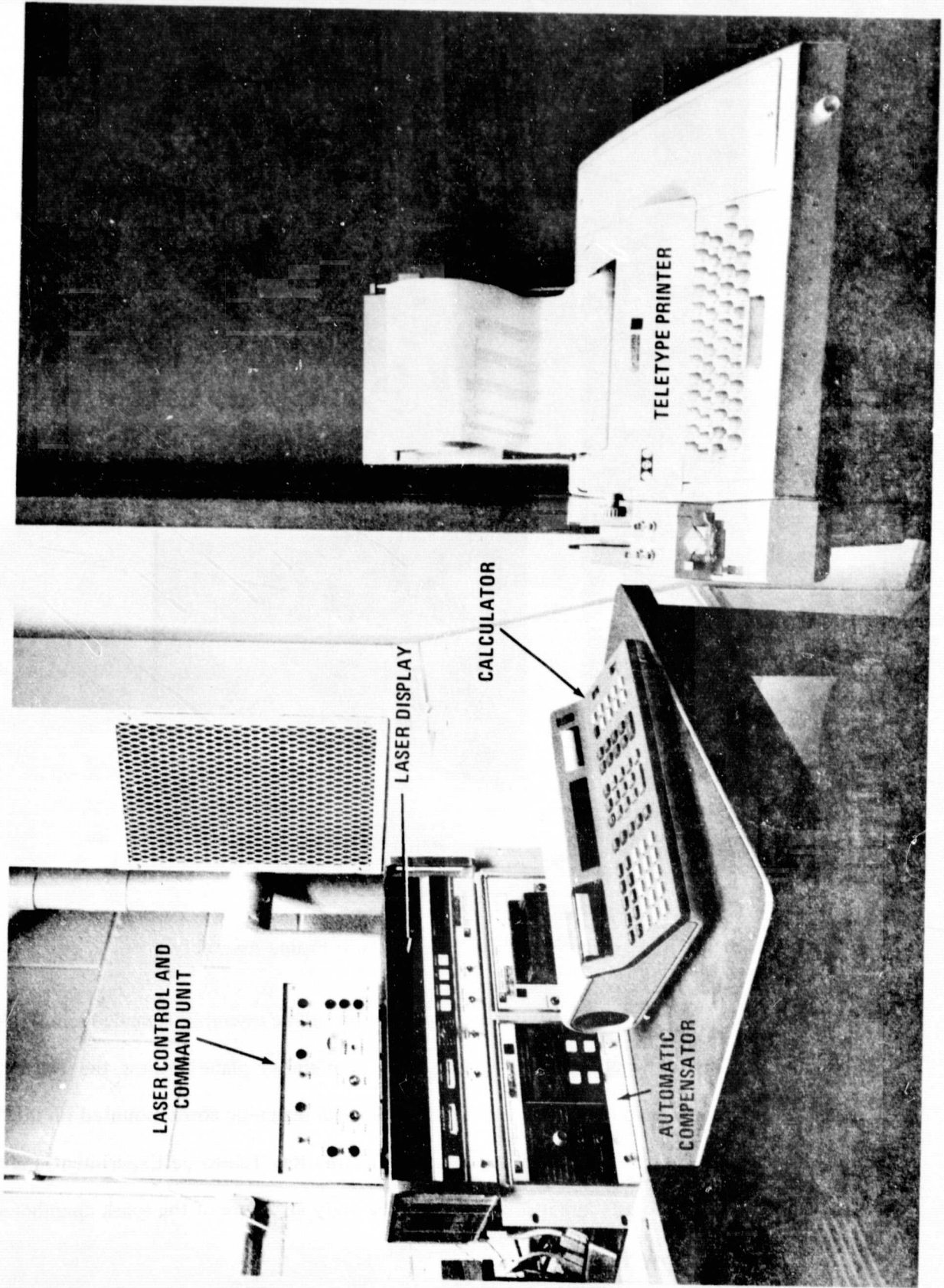


Figure 2. Recording and Display Units

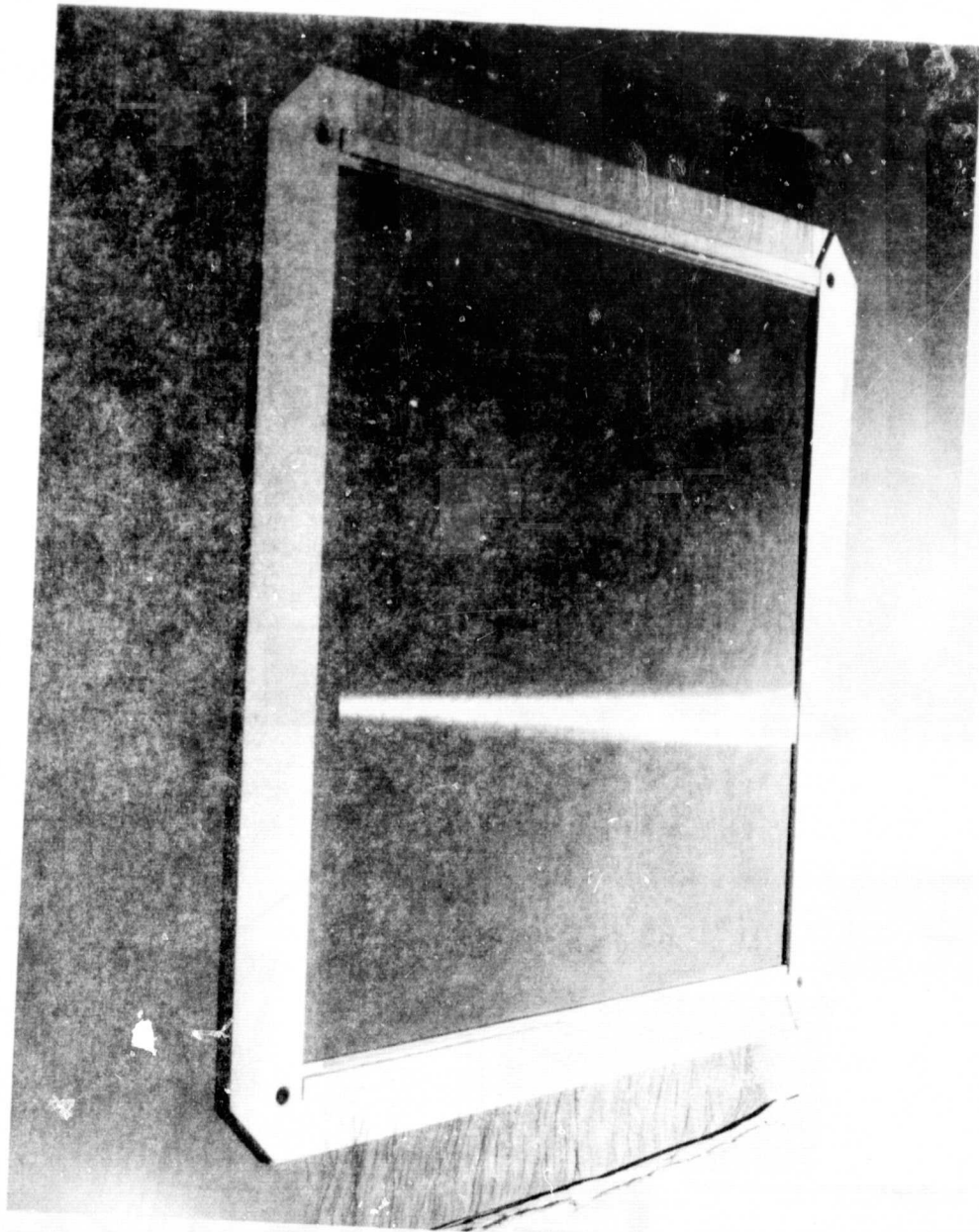


Figure 3. Wire-Wrapped Grid Frame Assembly

meet critical weight constraints. The wire wound on the frame assembly is made from 0.076 mm (0.003 inch) diameter beryllium copper wire stock. To maintain plane flatness, the wire strands are attached under tension to the frame and threaded through magnetic cores mounted on the "shelves" which form an integral part of the module. In the Gamma-Ray Telescope Experiment, Figure 5, 32 wire-wrapped frame modules are utilized to form the body structure of the spark chamber assembly.

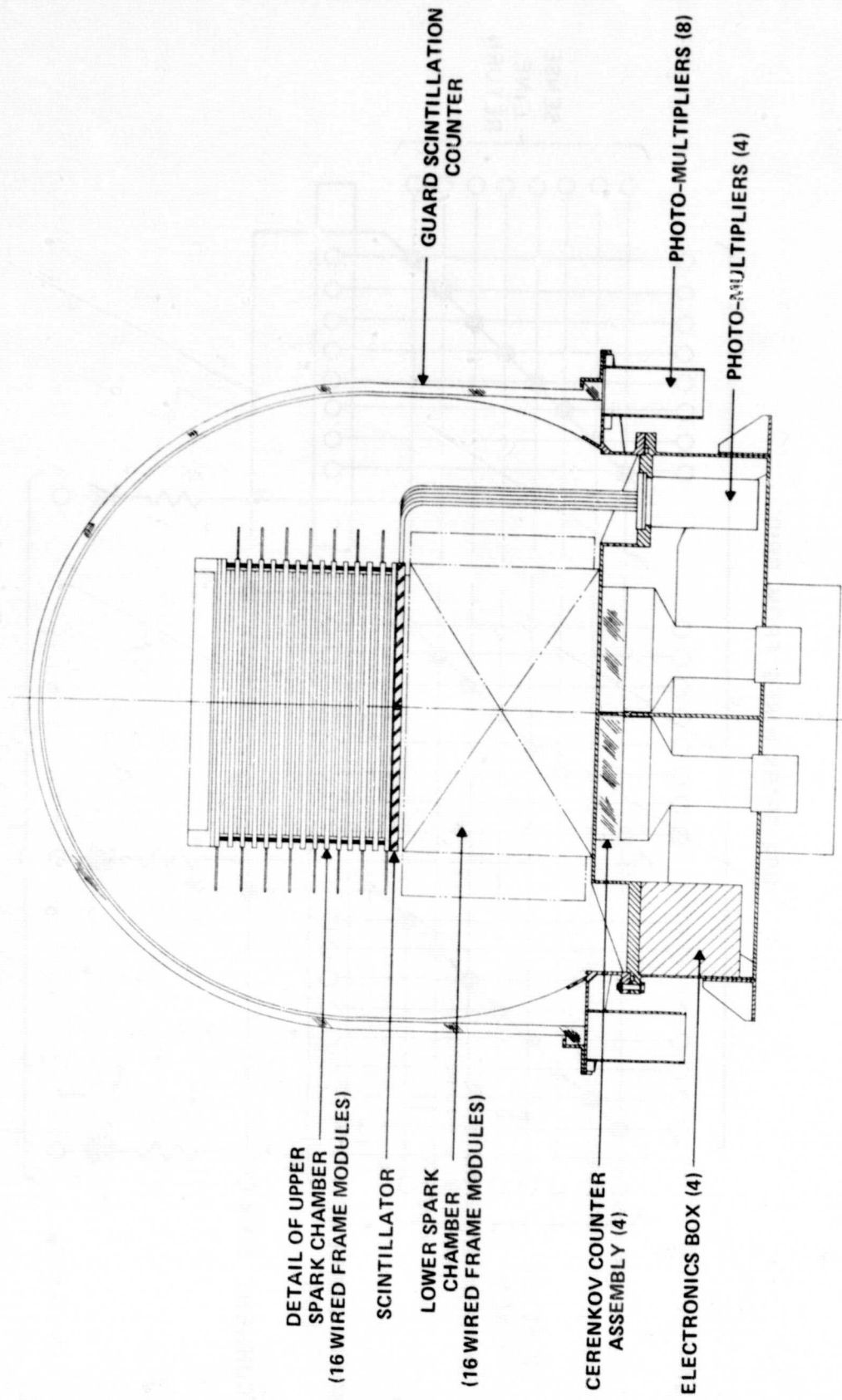


Figure 5. Gamma-Ray Telescope Experiment

THEORY OF OPERATION

The Laser Measuring System, Figure 6, has been successfully utilized in the measurement of wires on Egret-type spark frame assemblies within a demonstrated accuracy of ± 0.00635 mm (± 0.00025 inch). The laser head, Figures 1 and 18, supplies the laser beam for the system, part of which is sampled and applied to the reference detector which provides the lock and reference signals; the remainder of the beam is sent to the interferometer and reflector, Figure 1.

When a reflector is moved relative to its interferometer, the return light beam will be doppler shifted. The return light is directed to doppler detectors and amplified to provide the doppler signal for the laser display unit. The reference and doppler signals are converted to logic pulses, doubled in frequency and applied to the laser display calculator. The laser display unit permits a variety of averaging and velocity modes of operation, Figure 2.

Located on the movable supporting platform on either side of the stationary wired frame assembly is the light source and photodetector, Figures 1 and 7. During measurement, the supporting platform moves on its carriage towards the laser head. As the light source and detector pass a wire on the grid, the light is blocked by the wire which causes a voltage drop on the phototransistor of the photodetector circuitry. This voltage is amplified and used to activate the Schmitt trigger amplifier in the laser control and command unit, Figures 8 and 9. The output from the trigger amplifier is fed into the pulse shaping circuit, Appendix 1, whose output is a 3.5 V (approx.) square wave trigger signal. This output signal initiates the circuitry in the laser display and calculator units, Figures 2 and 6.

The calculator printout, Figure 10, lists the tape prompts and exact position for each wire strand exceeding tolerance by its designated number. The teletype printer also takes the data from the calculator and automatically prepares a teletype printout, Figure 11. The printout lists the wire number, the ideal position, the actual position, and the amount of error. When the error distance between wire strands exceeds the tolerance limit, the wire number is flagged as shown in Figure 12.

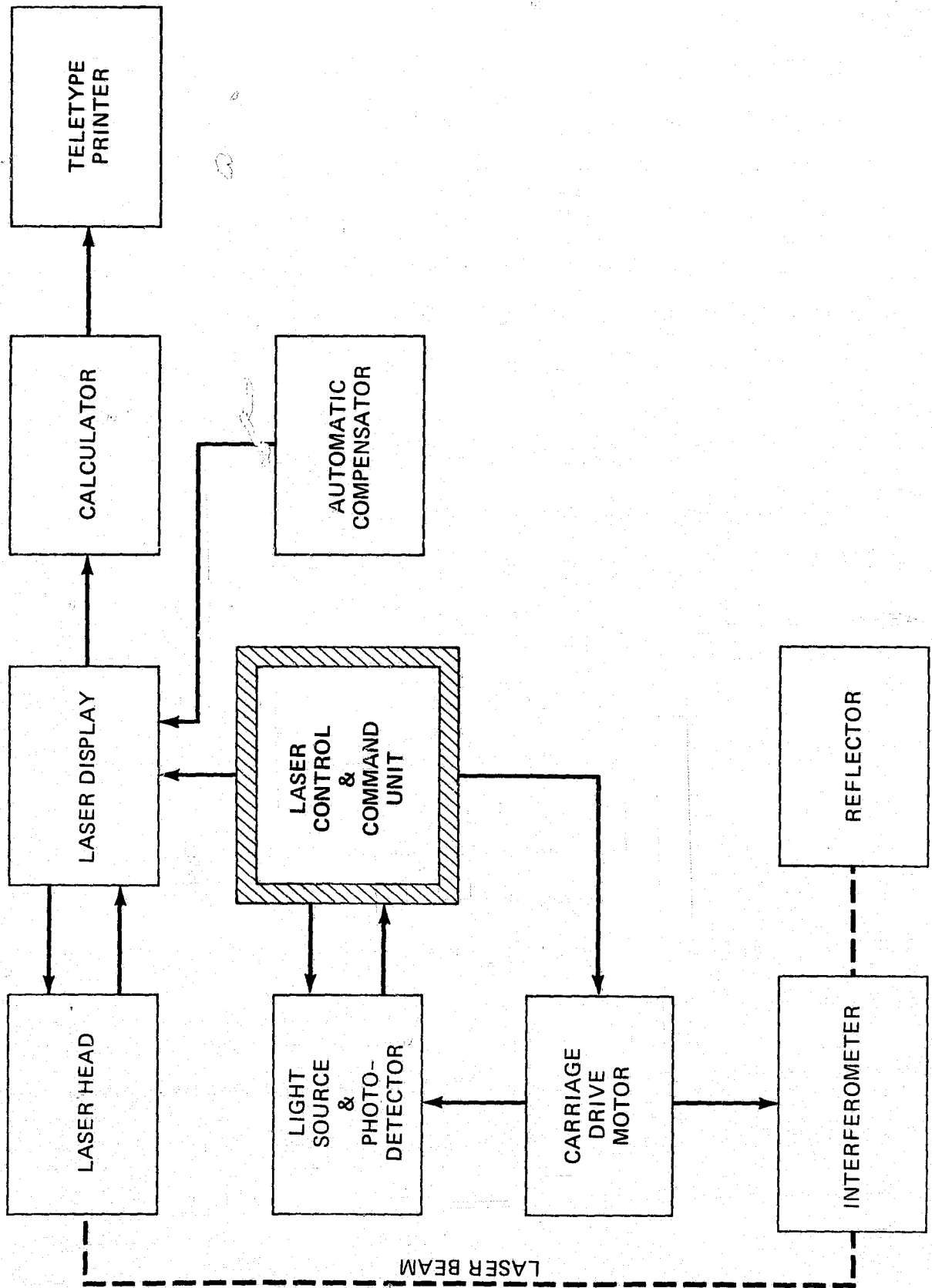


Figure 6. Laser System for Measuring Wire-Wrapped Frame Assemblies, Block Diagram

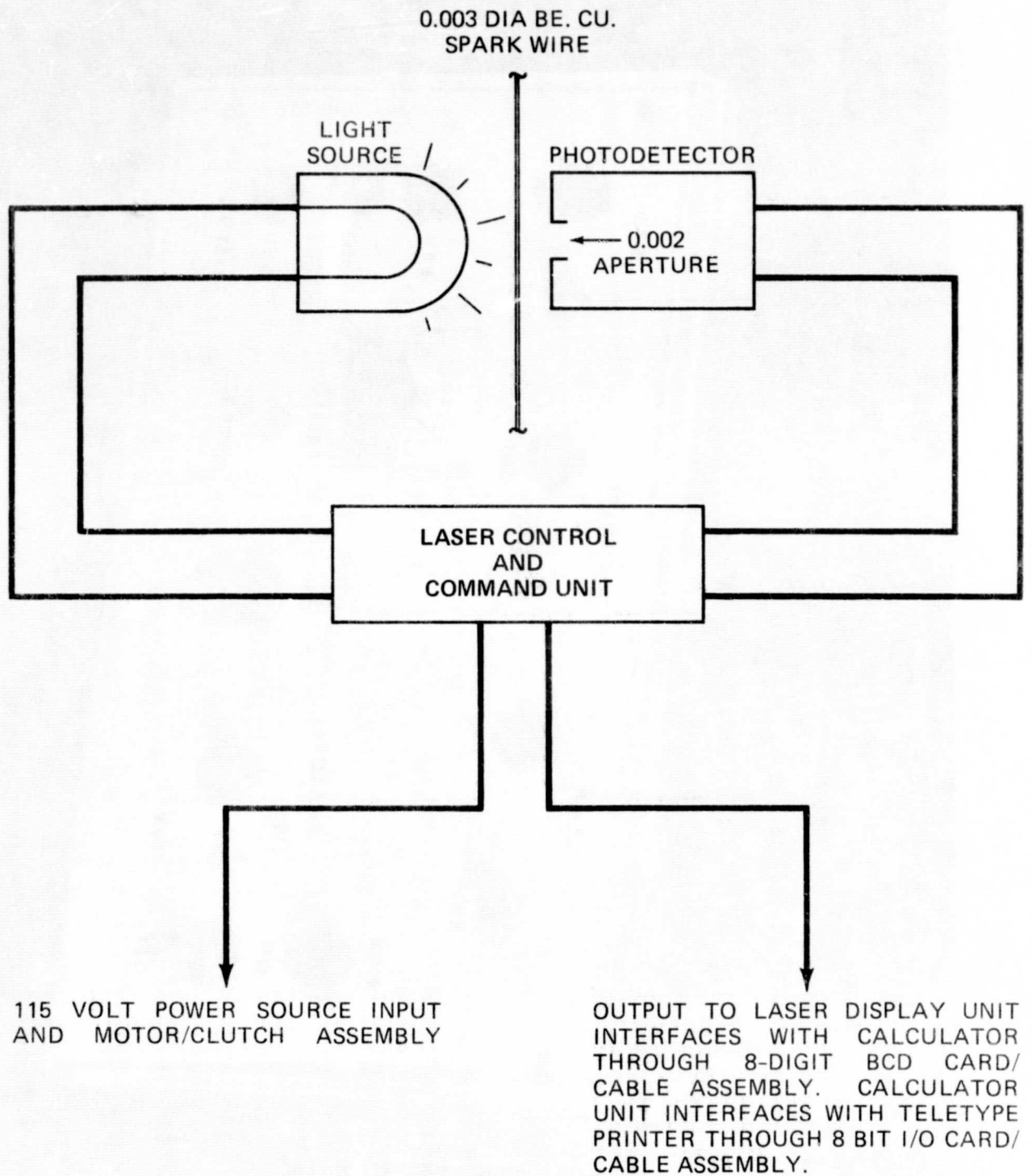


Figure 7. Photodetector, Light Source Assembly

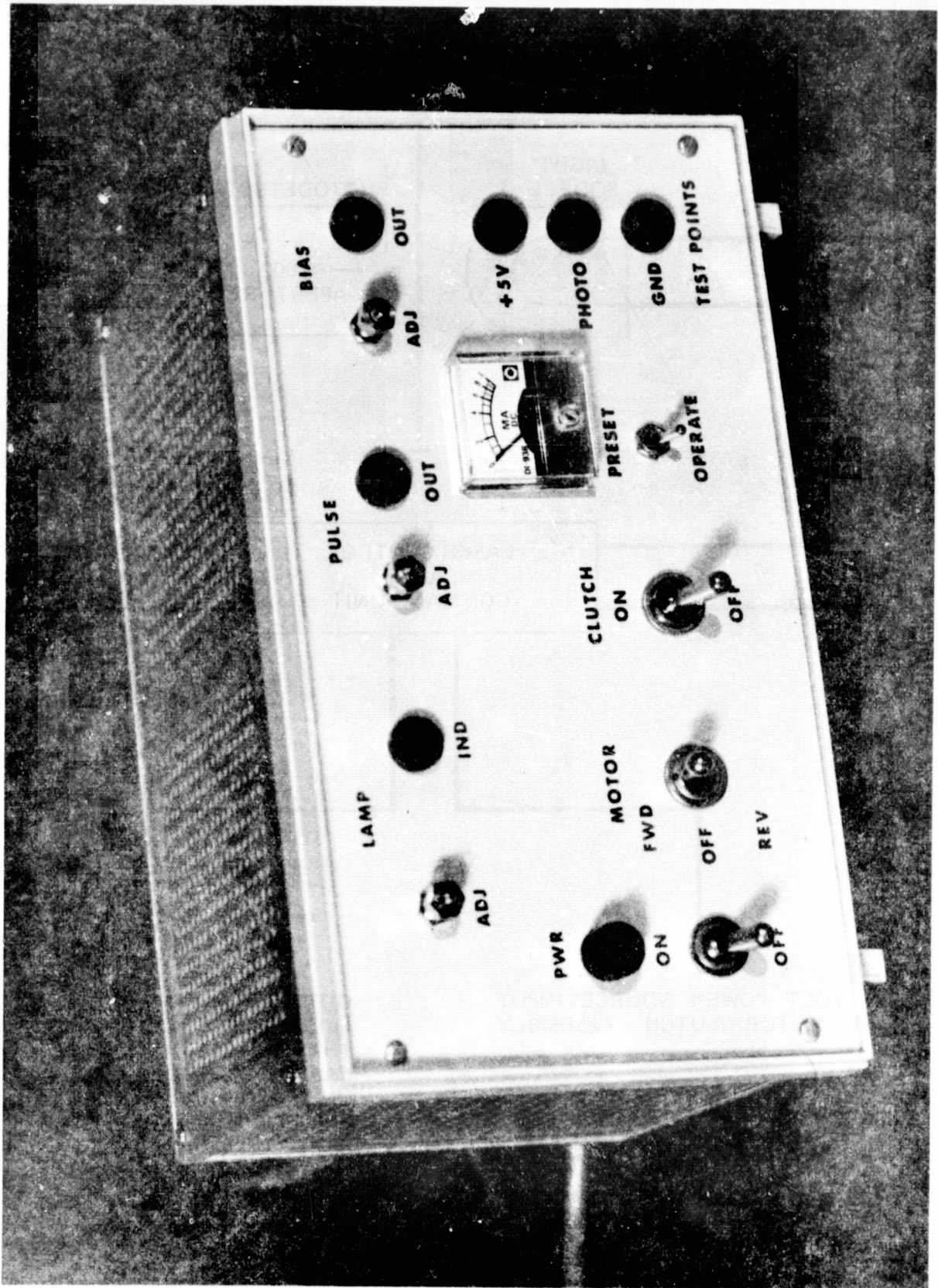


Figure 8. Laser Control and Command Unit

LASER CONTROL AND COMMAND UNIT SCHEMATIC DIAGRAM ANALYSIS

The laser control and command unit, Figures 8 and 9, was designed specifically for the Laser Measuring System. The circuitry consists of three (1/4 LM324) amplifiers: signal, Schmitt trigger, and meter indicator in addition to a pulse shaping circuit (Attachment 1), +5 V stepdown power supply (Attachment 2), and motor clutch switching assembly.

The signal amplifier receives the signal voltage from the photodetector and amplifies the signal (amplification factor 44:1) for the Schmitt trigger amplifier. The bias voltage of the signal amplifier can be adjusted with the "bias" control on the front panel of the laser control and command unit, Figure 8.

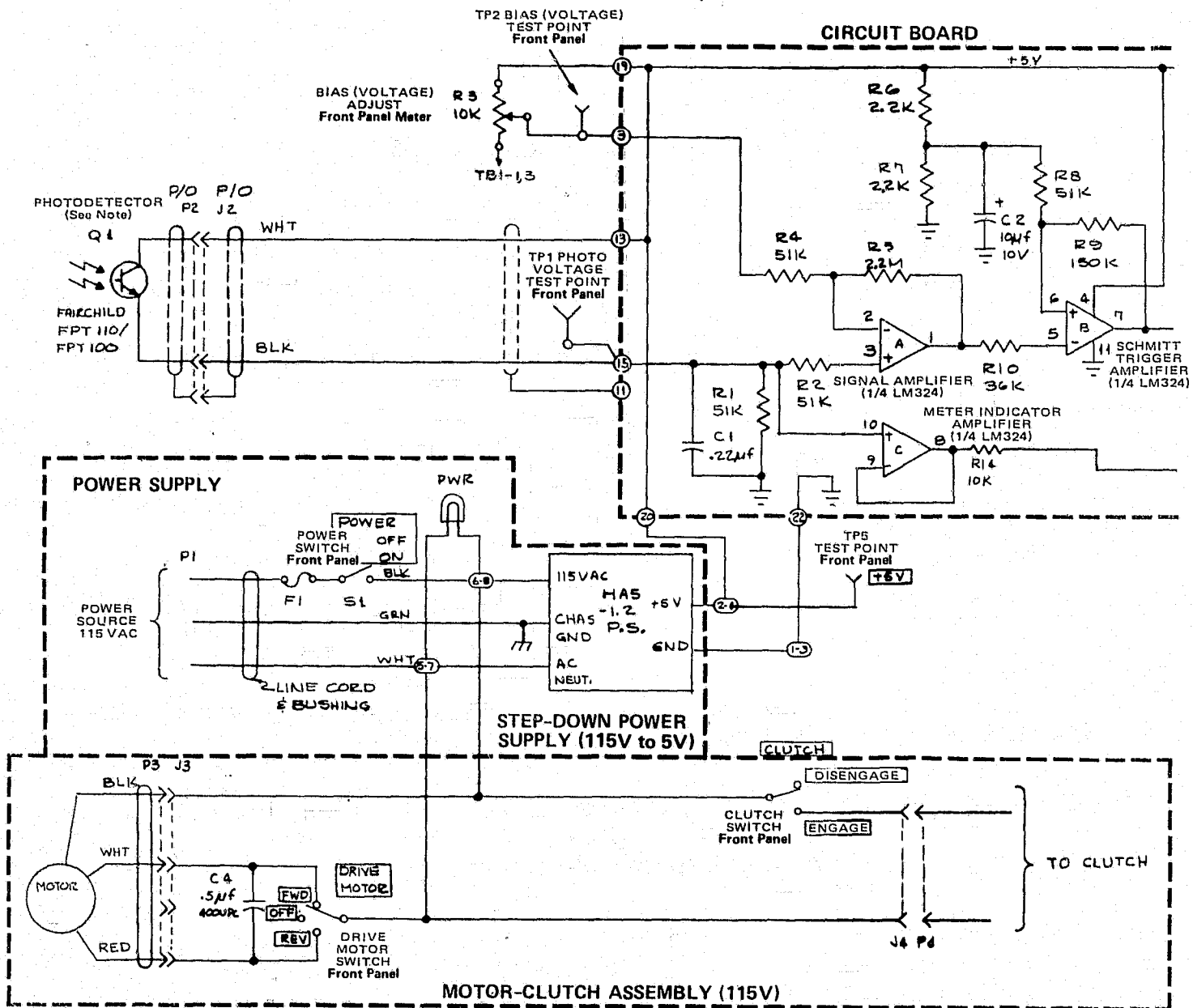
The Schmitt trigger amplifier is used to speed the transition time of the triggering signal. The output signal is fed into the pulse shaping circuit which generates a 3.5 V (approx.) square wave pulse that initiates the circuitry in the laser display, Appendix 3, and calculator units, Figure 6.

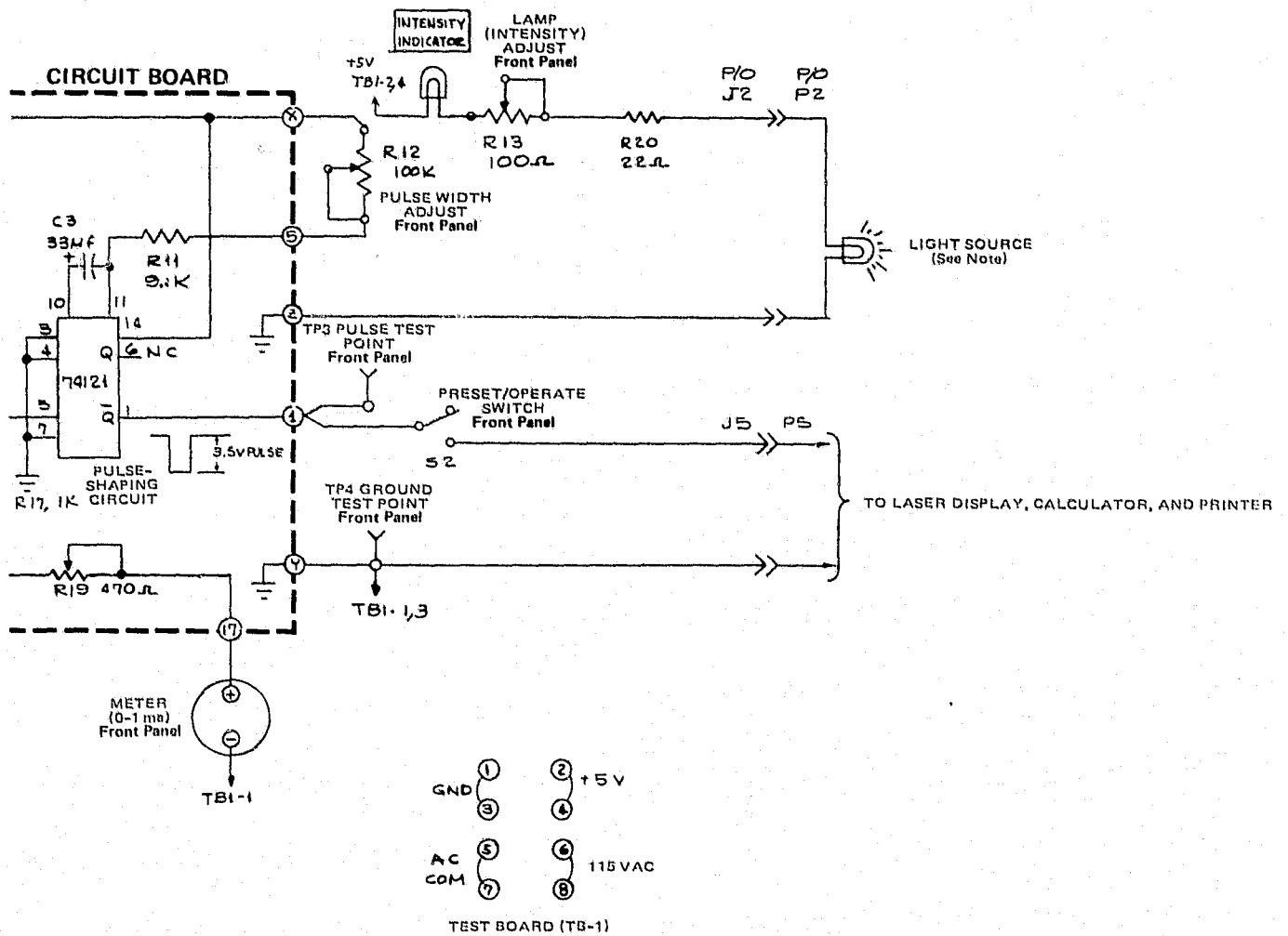
The width of the 3.5 V square wave can be adjusted with the "pulse" control on the front panel of the laser control and command unit, Figure 8. The function of the pulse shaping circuitry is to avoid a false trigger voltage caused by circuit noise appearing on the negative going trigger signal.

The meter indicator amplifier receives the voltage signal from the photodetector simultaneously with the signal amplifier. This voltage is amplified to peak the 0-1 milliamper meter on the front panel of the unit to indicate the presence of a wire strand, Figure 8. Refer to Table 1 for the laser control and command unit front panel switch settings and Table 2 for the laser control and command unit front panel test points and connector designations.

AUTOMATIC COMPENSATOR

The automatic compensator automatically and continuously corrects the laser display for air conditions (and material temperatures when desired), Figure 2. The compensator has an air temperature sensor, humidity sensor, and a barometer. A thumbwheel switch is included to allow entry of the coefficient of expansion of the carriage assembly. Up to three temperature sensors can be used to measure and average the temperature. The compensator uses the atmospheric measurements,





NOTE

BOTH DETECTOR AND LIGHT SOURCE UNITS FEED INTO PLUG (P2) AND JACK (J2).

Figure 9. Laser Control and Command Unit with Power Supply and Motor-Clutch Assemblies, Schematic Diagram

POSITION ERROR
PRINTOUT (10-4)

WIRE
NUMBER

```

NO = 15.0000
SPACING = 0.0320
TOL = 0.0015
FILE CODE = 0
POSN = 3.5250
START LASER GAGE
ERROR @ WIRE NO
TO LIST ENTER 1
LOAD DATA TAPE
FILE CODE
+0 +101 -0 -101
?
LOAD TELETYPE
TO LIST ENTER 1

```

TAPE
PROMPTS

```

15.0506
15.0508
15.0516
16.0523
16.0530
15.0538
16.0539
16.0540
16.0542
16.0543
15.0544
16.0546
15.0547
15.0548
16.0549
15.0550
16.0551
15.0552
15.0553
16.0554

```

Figure 10. Calculator Printout

```

FILE CODE          101
SPACING =         0.0320
TOL =             0.0015
POSN =            3.5250

```

FLG	WIRE NO.	IDEAL POSITION	ACTUAL POSITION	ERROR
	1	3.5250	3.5257	0.0007
	2	3.5570	3.5581	0.0011
	3	3.5890	3.5900	0.0010
	4	3.6210	3.6218	0.0008
	5	3.6530	3.6540	0.0010
	6	3.6850	3.6858	0.0008
	7	3.7170	3.7174	0.0004
	8	3.7490	3.7497	0.0007

Figure 11. Teletype Printout Showing Wire Strands Within Tolerance

```

@
FILE CODE          0
SPACING =         0.0320
TOL =             0.0015
POSN =            3.5250

```

FLG	WIRE NO.	IDEAL POSITION	ACTUAL POSITION	ERROR
###	1	3.5250	3.5223	-0.0027
###	2	3.5570	3.5547	-0.0023
###	3	3.5890	3.5870	-0.0020
###	4	3.6210	3.6190	

Figure 12. Teletype Printout Showing Wire Strand Numbers Flagged for Exceeding Tolerance

Table 1

Laser Control and Command Unit Front Panel Switches

Switch	Switch Position
Power	On/Off
Motor	Forward-Off-Reverse
Clutch	On/Off
Output Pulse	Preset/Operate

Table 2

Laser Control and Command Unit Front Panel Test Points and Connector Designations

Test Point	TP 1	Photodetector
	TP 2	Bias Voltage
	TP 3	Output Pulse
	TP 4	Ground Test
	TP 5	+5 Volt
	TB 1	Test Board
Connector	P 1	Power Source, 115 Volt
	P 2	Photodetector/Light Source
	P 3	Drive Motor
	P 4	Clutch Assembly

the temperature measurements and the coefficient of expansion to compute the overall compensation factor for the laser interferometer, Figure 1.

CALCULATOR

The calculator, Figures 2 and 13, is programmed to provide the data collection and listing routines for the system. The data collection routine obtains its initial position reading or setting from

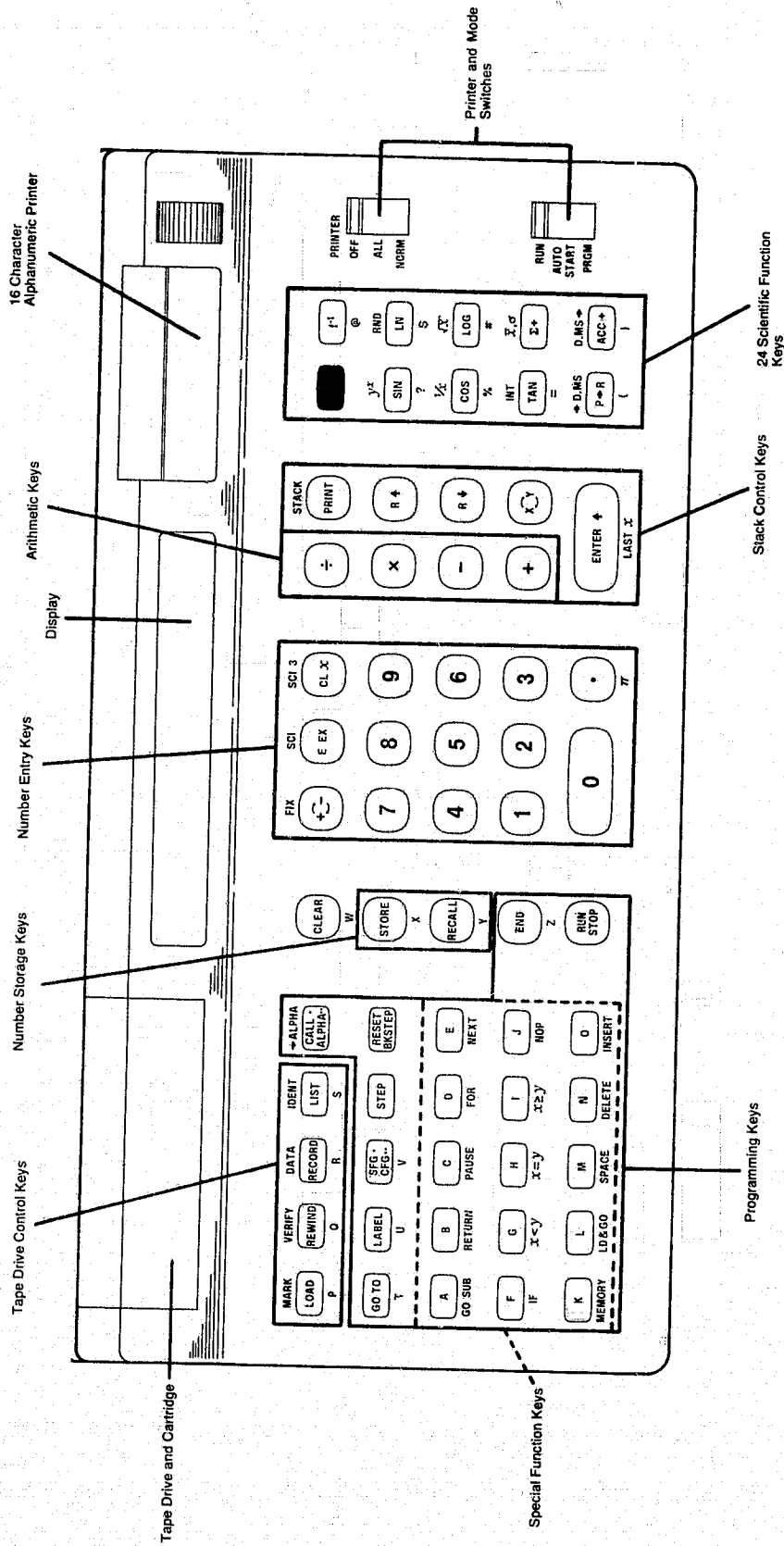


Figure 13. Calculator Keyboard

the edge of the grid frame assembly, Figures 3 and 7. The calculator records this location, with respect to that edge, for each wire on the frame. From this position, the calculator determines the exact location for each wire on the frame.

The predetermined location for each wire is based on the operator supplied ideal wire position data (prerecorded programmed instructions) which is compared to the measured wire position on the frame. The calculator provides a printout (strip printer) for the positional error and the number of each wire which falls outside the operator-supplied tolerance limit, and automatically corrects for missing wires on the frame assembly, Figure 10.

The listing routine produces a formatted listing from the data tape and generates a histogram of errors. The formatted listing consists of a paged printout with a heading on each page followed by a specified number of data lines. Each line consists of a flag indicator for out-of-tolerance wires, ideal wire position, measured wire position, and positional error. The last line of the listing also contains the mean error and standard deviation of error. The listing routine from the calculator is fed into the teletype printer, Figures 2 and 6.

TAPE CARTRIDGE

The calculator tape drive assembly, Figure 14, is used for loading the prerecorded program instructions into the calculator. The specially designed cartridge, Figure 15, contains approximately 140 feet of metal-oxide tape. When the cartridge is removed from the tape drive, a small plastic cover snaps closed to protect the tape from dust and dirt. Positioning the "RECORD" slide to the left protects the tape from accidental erasure. The "RECORD" slide should be positioned to the right only when recording or erasing.

SAFETY PRECAUTION

WARNING

LASER BEAM

This instrument emits laser light. The power output of the HP laser is low in comparison to most other lasers, either continuous wave or pulsed, but due to the high brilliance factor, the output beam of any laser should never be allowed to strike the eye directly. It is the considered opinion of Hewlett-Packard Company that the light beam from this device presents NO hazard to health and safety. However, the existence of newly enacted federal regulations with respect to laser devices together with the lack of any widely accepted standards of laser power safety thresholds requires the insertion of this warning statement.

OPERATING PROCEDURES

1. Turn "ON" Laser Control and Command Unit, Figure 8, "PWR" for system operation. The "MOTOR" and "CLUTCH" switches should be in the "OFF" position.

NOTE

The calculator, automatic compensator, and teletype printer should always be set to the "ON" position to enable master power switching on the laser control and command unit.

2. Align light source and photodetector units on a spark wire for maximum meter deflection on the laser control and command unit.
3. For checking alignment across the wire grid frame and light/photo detector triggering mechanism, manually move the supporting platform along the length of the wire frame. Be sure the power "CLUTCH" switch is in the "OFF" position.
4. Adjust carriage so that the light source and photo detector are set outside the edge of the wired frame assembly.
5. Depress "RESET" button on laser display unit to zero laser display.
6. Insert PROGRAM tape in calculator, Figure 14, (tape drive and cartridge location).
7. Depress REWIND key on calculator, Figure 13, (tape drive control key location).
8. Depress "O" key and enter program access code (3) in calculator, (number entry key location).
9. Depress "LOAD" key on calculator (tape drive control key location). Calculator screen (display location) will display the program access code (3).
10. Depress "END" key on calculator (special function key location).
11. Remove PROGRAM tape from calculator (tape drive and cartridge location).
12. Insert DATA tape (tape drive and cartridge location).

NOTE

Be sure DATA tape key is set for Record.

13. Depress LOAD key (tape drive control key location).
14. Depress "RUN" key (special function key location). Calculator screen should display 50.00 as programmed.

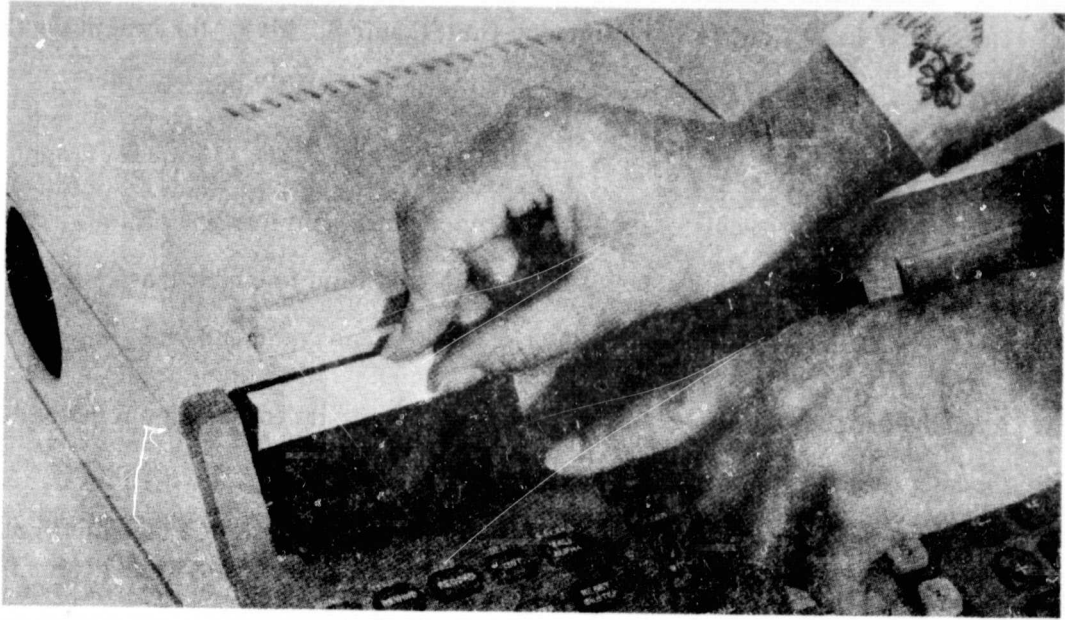


Figure 14. Inserting Tape Cartridge Into Calculator Tape Drive

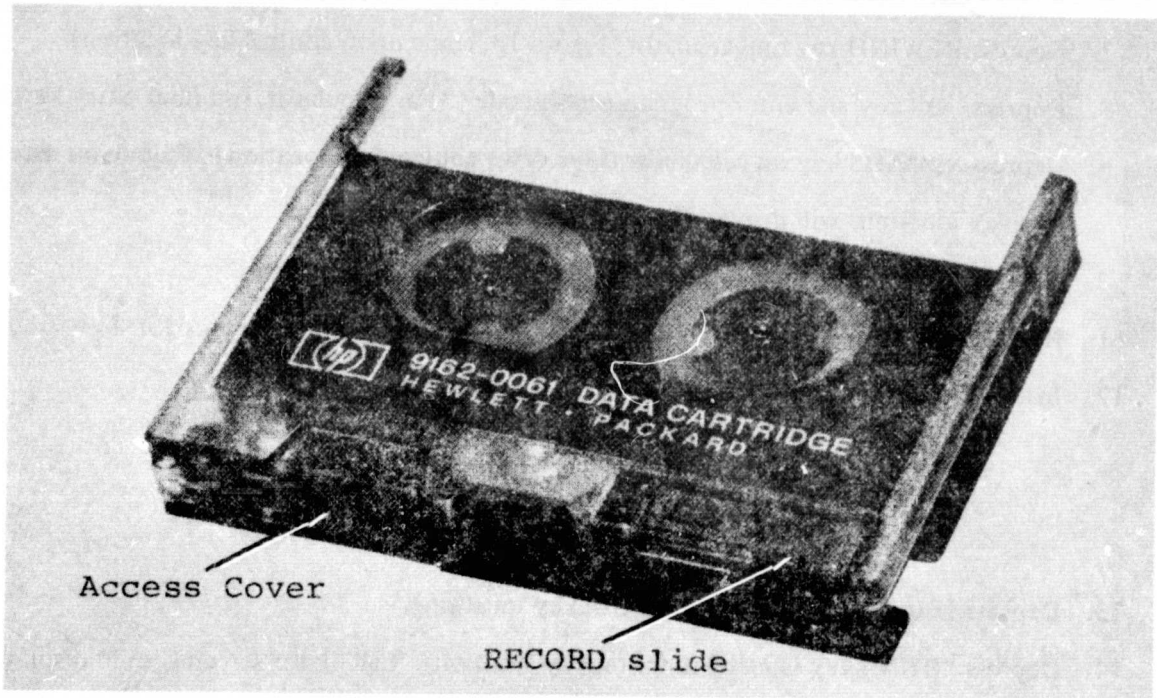


Figure 15. Tape Cartridge

15. Follow tape prompts, Figure 10, (calculator alphanumeric printer).
16. Set carriage drive "MOTOR" switch to "FWD" or "REV" position as required on laser control and command unit, Figure 8.
17. Turn drive motor "CLUTCH" switch to "ON" position to initiate laser measuring system.
18. The calculator printout automatically lists each out of tolerance wire number and tolerance dimension, Figure 10. At end of run, set motor "CLUTCH" switch "OFF".
19. Set teletype printer to "LINE" position.

NOTE

Calculator printer and mode switches should be set to "NORM" and "RUN" positions.

20. Depress "RUN/STOP" key to load teletype printer. Refer to Figure 12 for teletype printout.
21. Depress "RUN/STOP" key to end run.

NOTE

Refer to Table 3 for Laser Measuring System manufacturer's model numbers.

Table 3
Laser Measuring System Components

Unit	Manufacturer	Model Number
Laser Head	Hewlett Packard	5500C
Laser Display	Hewlett Packard	5505A
Calculator	Hewlett Packard	9815A
Teletype Printer	Teletype Corp.	33
Automatic Compensator	Hewlett Packard	5510A
Interferometer	Hewlett Packard	10565B
Reflector	Hewlett Packard	10550B
Photodetector	Fairchild	FPT110
Light Source	General Electric	222
Laser Control & Command Unit	GSFC Designed Unit	Refer to Figures 8 and 9

AUTOREFLECTION ALIGNMENT PROCEDURES

In the autoreflection alignment method, the reflector (Model 10550B), Figure 16, is mechanically aligned with its reflecting face vertically and horizontally perpendicular to the measurement line of travel, Figure 17. The laser head is set at least 20 inches from the reflector and adjusted so that the laser beam is reflected back by the reflector to the center beam exit port of the laser head turret. Hoke blocks may be used to verify the distance from laser head to reflector.

The purpose of the autoreflection alignment method is to minimize cosine error and ensure that the laser beam is parallel to the measurement axis. Align the laser head in the following manner.

1. To determine the line of travel to be measured, place the reflector at the far end of travel, Figure 17. The reflector should be positioned more than 20 inches from the laser head. Take the magnetic template from the 10565B remote interferometer and center it on the front of the reflector.
2. Adjust the reflector so its face is vertically and horizontally perpendicular to the laser carriage.
3. Position the laser head so the laser beam is directed at the top aperture of the template. Turn the small aperture in the laser head turret to the output hole.
4. Carefully adjust the laser head position to center the reflected beam from the reflector on the center beam exit aperture of the laser head. The laser beam should remain centered in the aperture of the template. The reflected beam will appear as a "halo" around the small exit port.
5. Position the remote interferometer for maximum BEAM ALIGNMENT meter indication. Check alignment at the near and far end of travel and verify that the reflected laser beam remains centered in the appropriate Display A return port, Figure 18.

CONCLUSION

The Laser Measurement System has the potential of being updated to further expand its capabilities for performing precise, automatic measurements of wire positions on frame assemblies. One method of improving the system would be to locate the light source and photodetector on the same



Figure 16. Reflector Mirror

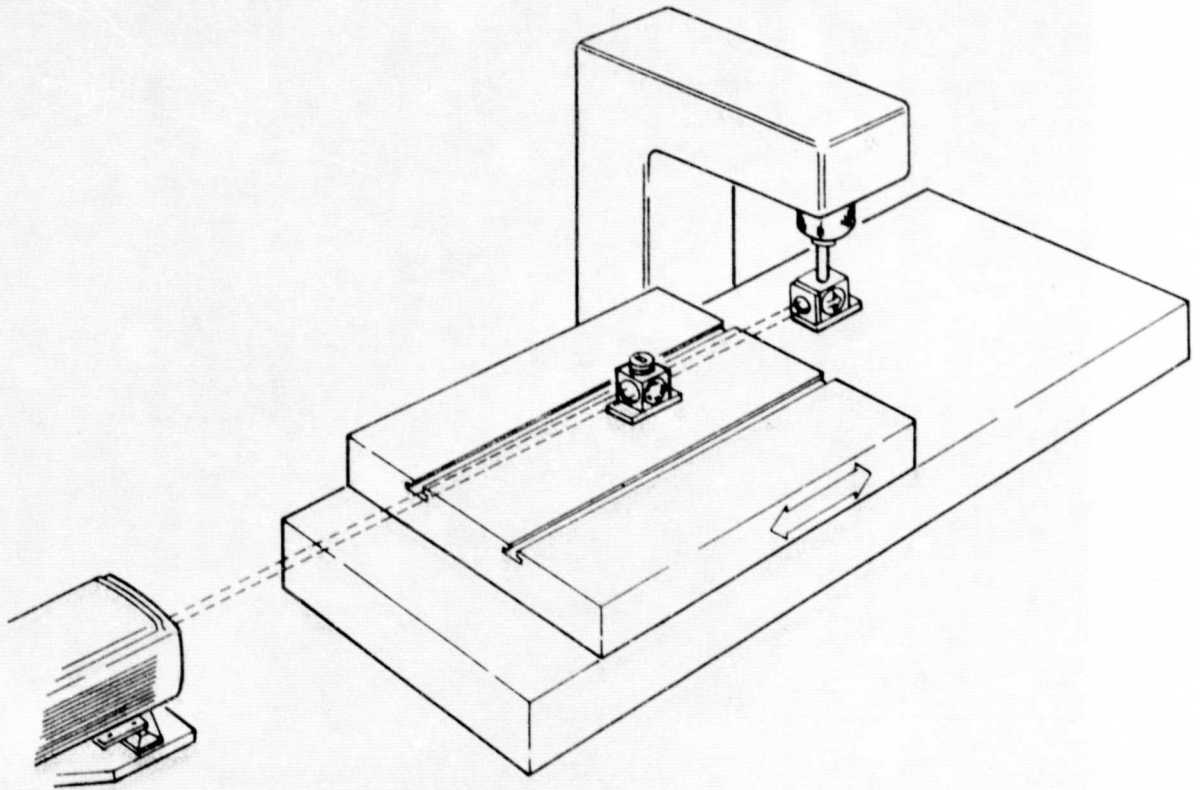


Figure 17. Laser Linear Measurement Setup

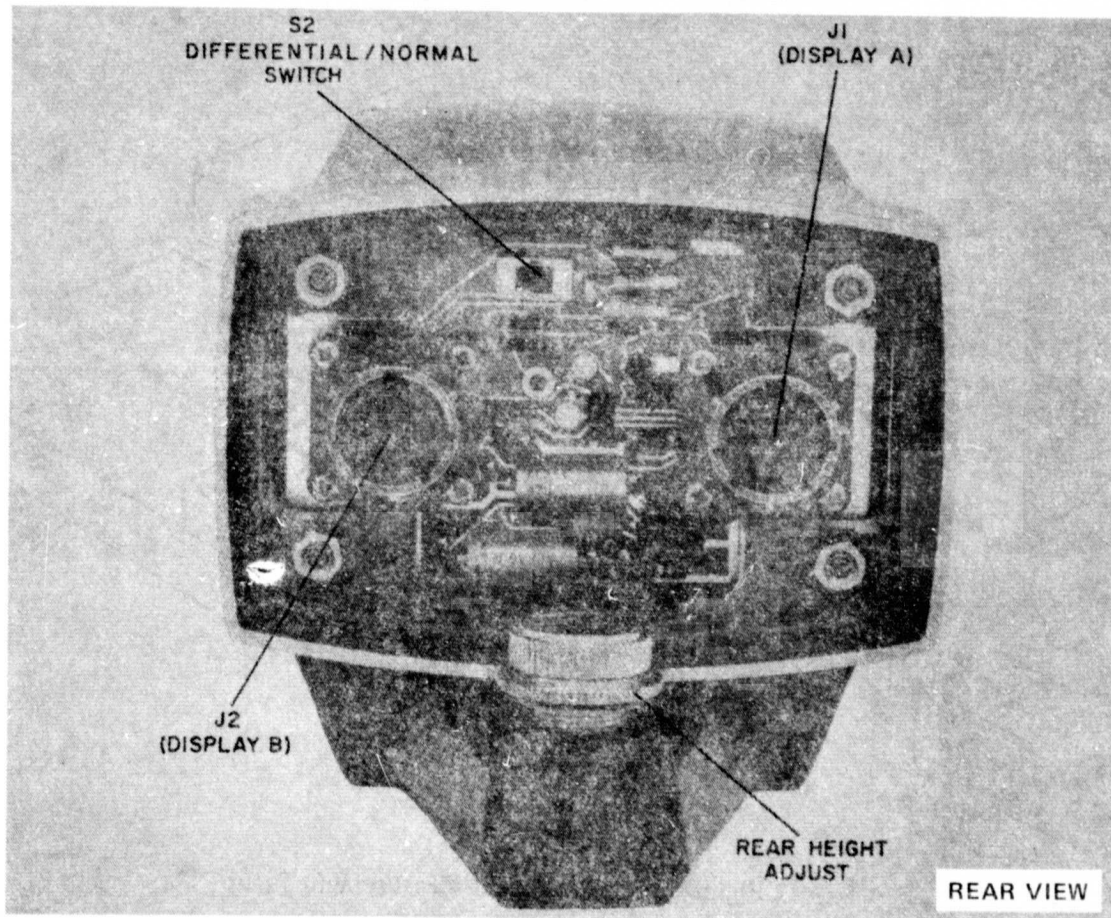
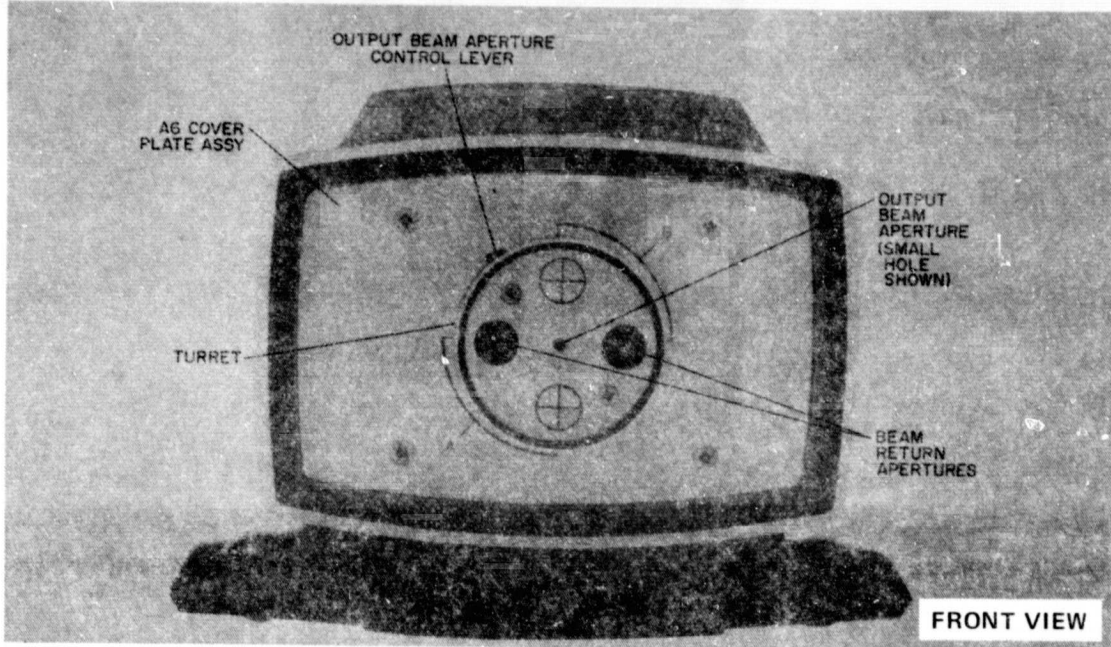


Figure 18. Laser Head Front and Rear Views

side of the wire plane to facilitate measuring frames which utilize more than two wire planes, for example, multiwire proportional counters. The system could also be updated to eliminate the need for mutual alignment of the light source and photo detector.

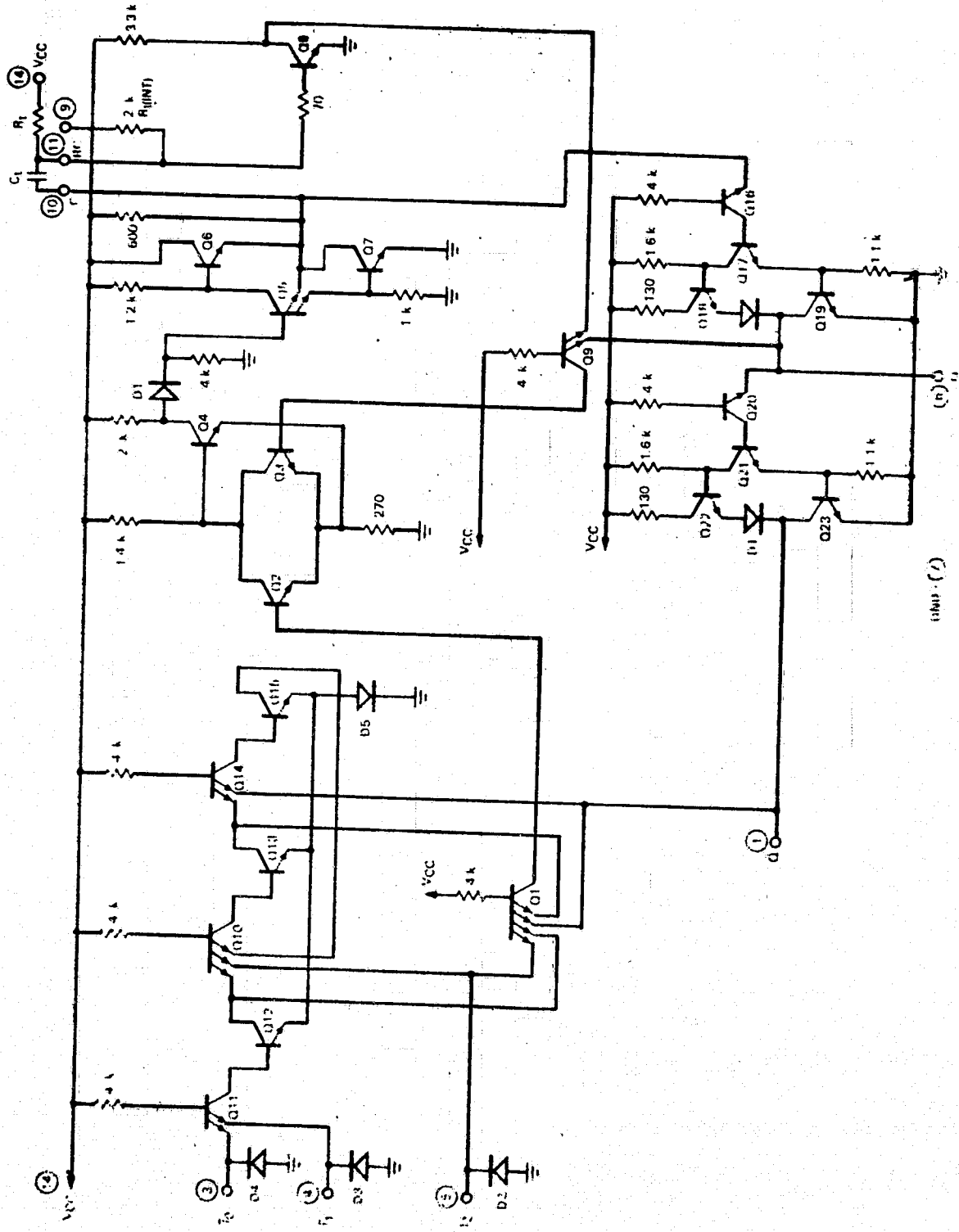
The possibility of installing the Laser Measurement System as an integral part of a wire application machine is also being considered. The system could also be utilized as an in-process inspection tool. A further expansion of the system could be the incorporation of an automatic feedback control for positioning wires and/or adjusting them for out of tolerance conditions.

ACKNOWLEDGMENTS

The authors wish to acknowledge the work of Mr. Charles H. Ehrmann, Data Systems Section, and Dr. George A. Simpson, Gamma Ray and Nuclear Emulsions Branch, for development of the laser calculator program; Mr. Robert M. Steudl, Spacecraft Devices Section, for redesign of the laser carriage assembly; and Mr. David B. Friedman, Publications Section, for technical writing services.

APPENDIX 1

PULSE SHAPING CIRCUIT



Pulse Shaping Circuit - 9603/74121 Monostable Multivibrator

APPENDIX 2

STEP-DOWN POWER SUPPLY

(115 to 5 V)



POWER-ONE, Inc.
 531 DAWSON DRIVE
 CAMARILLO, CALIF. 93010
 (805) 484-2806

APPLICATION DATA INCLUDING:

1. Schematic
2. Parts List
3. Specifications
4. Outlines & Mounting Dwg.
5. General User Information

MODEL

HA5-1.2/OVP
 HA15-0.5

SPECIFICATIONS

AC Input: 115/230VAC $\pm 10\%$ 47-440 Hz (Derate unit 10% at 50 Hz operation)

DC Output:

Model	Voltage	Current (Amps)	OVP
HA5	5	1.2	6.2 \pm .4V
HA15	9 to 15	.5	NA

Line Regulation: $\pm 0.05\%$ for a 10V input change

Load Regulation: $\pm 0.05\%$ for a 50% load change

Output Ripple: 1.5 mV PK-PK, 0.4 mV RMS

Transient Response: 30 μ sec for 50% load change

Overload & Short Circuit Protection: Automatic current limit/foldback

Reverse Voltage Protection: Reverse protection on output

Stability: $\pm 0.05\%$ for 24 hours after warmup

Input Fusing: See Table

Temperature Coefficient: 0.01%/ $^{\circ}$ C maximum, 0.002%/ $^{\circ}$ C typical

Cooling: Units are full rated to 50 $^{\circ}$ C in free air, must be derated or fan cooled when mounted in confined area

Temperature Rating: 0-50 $^{\circ}$ C - 100%
 60 $^{\circ}$ C - 70%
 71 $^{\circ}$ C - 40%

Efficiency: @ 115 VAC, full load on output
 5V & 6V - 40%
 12V & 15V - 50%

Note: In systems where the AC voltage is controlled, operate at 100-110 VAC for greatest efficiency

Construction: All aluminum chassis

Weight: 1 lb.

Vibration: Per Mil-Std-810B, Method 514, Procedure I, Curve AB (to 50 Hz)

Shock: Per Mil-Std-810B, Method 516, Procedure V

2 YEAR GUARANTEE

POWER-ONE will repair or replace any power supply of its manufacture that does not perform to published specifications as a result of defective materials or workmanship for a period of 2 years from date of original purchase. No other obligations or liabilities are implied or expressed. Returns must be freight prepaid.

TROUBLESHOOTING GUIDE

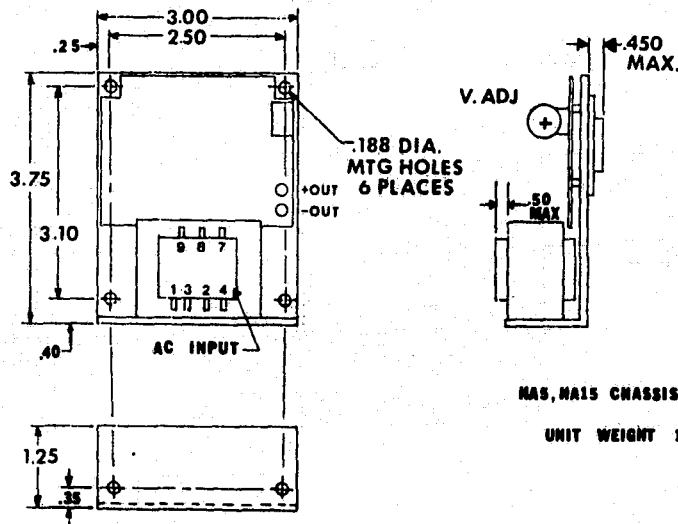
Refer to voltage test points shown on schematic for ease of failure determination

MODEL HA5, HA15

SYMPTOM	POSSIBLE PROBLEM
Unit Overheating	<ol style="list-style-type: none"> 1. Output overloaded 2. Inadequate ventilation 3. Improper transformer primary connection 4. High input AC voltage
Low Output Voltage With High Ripple	<ol style="list-style-type: none"> 1. Output overloaded 2. U1 faulty 3. CR1, CR2 or CR3 open 4. C1, C2 or C3 leaky 5. Q1 open 6. R13 open
High Output Voltage and Ripple, Poor Regulation	<ol style="list-style-type: none"> 1. Q1 or Q2 shorted 2. U1 faulty 3. R14 open 4. R10 shorted
High Input Current, Blows Fuses	<ol style="list-style-type: none"> 1. Improper input voltage or frequency 2. C1 or C2 shorted 3. CR1, CR2 or CR3 shorted

AC CONNECTION & FUSE TABLE

For Use At	Primary Fuse At	Connect	Apply Power To
115	.25A	1-3,2-4	1 & 4
230	.125A	2-3	1 & 4



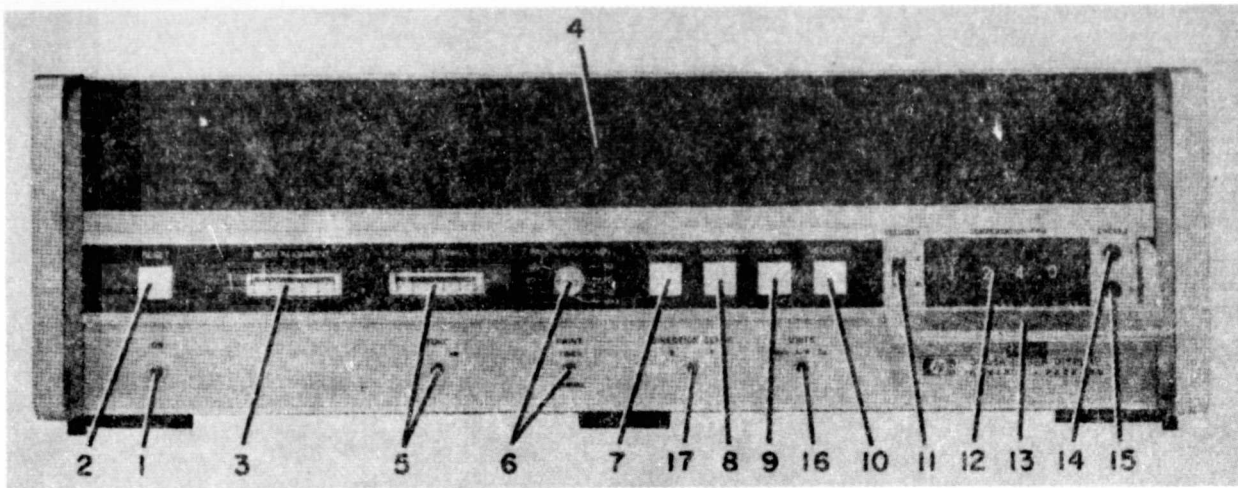
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Step-Down Power Supply (115 to 5 V)

APPENDIX 3

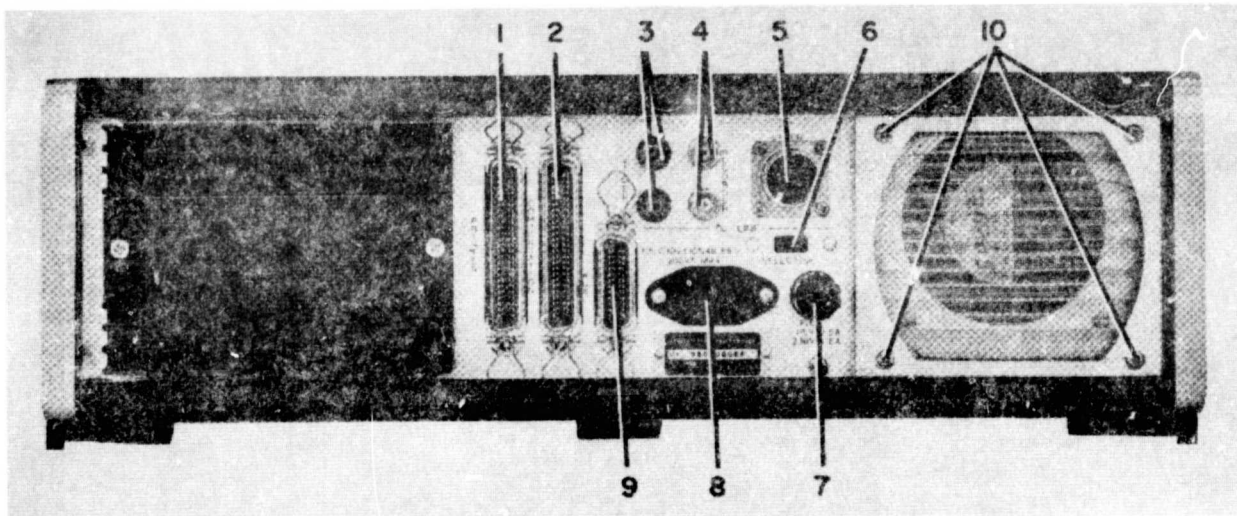
LASER DISPLAY AND PRINTOUT UNIT CONTROLS AND INDICATORS

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- | | |
|--|------------------------------------|
| 1. System power switch | 10. Velocity pushbutton |
| 2. Reset pushbutton: beam alignment and laser tuning | 11. Velocity switch |
| 3. Beam alignment meter | 12. Compensation - PPM thumbwheels |
| 4. Display readout panel | 13. Air compensation table |
| 5. Laser tuning meter and tune switch | 14. Checks 1 switch |
| 6. Prints-plots/min and Print switches | 15. Checks 2 switch |
| 7. Normal pushbutton | 16. Units switch |
| 8. Smooth pushbutton | 17. Direction sense switch |
| 9. X10 pushbutton | |

Display and Printout Unit, Front Panel Controls and Indicators



- | | |
|---------------------------|---------------------------------|
| 1. Printer connector | 6. Selector switch |
| 2. Compensation connector | 7. Fuse receptacle |
| 3. Timer jacks | 8. 115/230 v ac receptacle |
| 4. Recorder connectors | 9. Auxiliary connector |
| 5. Laser connector | 10. Air filter retaining screws |

Display and Printout, Rear Panel Controls and Connectors