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# Laser Measuring System for Wire-Wrapped Frame Assemblies

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**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

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#### 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 ninetytwo 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

1



Figure 1. Wired Frame and Laser Carriage Assemblies



Figure 2. Recording and Display Units

3



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.

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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  $\pm 0.00635$  mm ( $\pm 0.00025$  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.

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Figure 7. Photodetector, Light Source Assembly



Figure 8. Laser Control and Command Unit

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#### 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), +5V 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 pulseshaping 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 milliampere 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,



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4.





		POSITION ERROR PRINTOUT (10-4)	WIRE NUMBER
			15.0506
NO = 15.0000			15.0508
SPACING = 0.0320	and the second second		15.0516
TOL = 0.8015	and the second		16.0523
FILE CODE = $0$			16.0530
POSN = 3.5250	New Street		15.0538
START LASER GAGE			16.0539
ERROR @ WIRE NO	TAPE		16.0540
TO LIST ENTER 1	PROMPTS		16.6542
LOAD DATA TAPE			16.0543
FILE CODE			15.0544
+0 +101 -0 -101			15.0346
?			15.0547
LOAD TELETYPE			15.0548
TO LIST ENTER 1			16.0549
· J			15.0550
			16.0551
			15.0552
			15.0553
			16.0554



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

<b>@</b>			
FILE CODE	, and the second se		
SPACING =	0.0320	tan ing kanalang <u>an</u> ang kanalang kanalang kanalang kanalang kanalang kanalang kanalang kanalang kanalang kanala	in an an trainn an Alla. An an Alla Anna Anna Anna A
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

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

#### Laser Control and Command Unit Front Panel Switches

#### Table 2

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

	TP 1	Photodetector
	<b>TP 2</b>	Bias Voltage
Point	TP 3	Output Pulse
Test ]	TP 4	Ground Test
	TP 5	+5 Volt
	TB 1	Test Board
	P 1	Power Source, 115 Volt
ector	P 2	Photodetector/Light Source
Conn	Р 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



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 accidential 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).
- 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

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- 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.

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#### 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.

- 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 approx riate 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.

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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

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## **APPENDIX 1**

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# PULSE SHAPING CIRCUIT

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## APPENDIX 2

## STEP-DOWN POWER SUPPLY

(115 to 5 V)



Step-Down Power Supply (115 to 5 V)

RES DES	HAI55	STD PK	HA5-1.2 OVP	STD PN	DESCRIPTION
CI,5	100/35	101-10110	220/16	101-10107	CAPACITOR, FLECT
C2.3	330/35	101-10109	1000/16	101-10108	CAPACITOR, FLECT
C4	.001/100	104-10093	.001/100	104-10093	CAPACITOR. MYLAR.
CRI, 2,3,4	AEIC	111-10251	AEIC	111-10251	DIODE, IA 200V
CR5		[. ———	1N752A	112-10006	DIODE ZENER
· · ·					
SCRI			S0303LS3	160-10258	SCR 3A
QI	12500-3	171-10261	12500-3	171-10261	TRANSISTCR, NPN
RII	IK	151-10365	220-~	151-10349	RESISTOR 1/2W5%CF
RI2	······		47-~-	151 - 10333	
R2	2.2K	151-10373	47-~	151 - 10333	
R5	220-~	151-10349	220	151 - 10349	
R3			· · · · · · · · · · · · · · · · · · ·		
R4	1~	151-10300		·	
R6	4.7K	151-10381	1.6K	151-10370	
RIO	1.6K	151-10370	3.3K	151 - 103 '7	<b>F</b>
R9	300	151-10352	6.8 ~	151 - 10313	1/2 W 5% CF
RI3	47-1-CF	151-10333	750- MF	152-10502	CF DR MF
RI4			1.2K	152-10507	1 1/2W 2%MF
R4			,39 <b>r</b>	158-10081	RESISTOR 2W BWH
R8	1.5K	155-10085	1.5K	155-10085	POTENTIOMETER 2W WW
					,,
UI	1 Ja 723	130-10267	1 123	130-10287	IC VOLTAGE REGULATOR
TI	12573	082-12573	12569	052-12573	TRANSFORMER
CHASIS	12567	412-12576	12567	412-12576	CHASISS
P.C.B.	12574	505-12574	12574	505-12574	P. C. BOARD



**APPENDIX 3** 

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LASER DISPLAY AND PRINTOUT UNIT CONTROLS AND INDICATORS

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- 1. System power switch
- 2. Reset pushbutton: beam alignment and laser tuning
- 3. Beam alignment meter
- 4. Display readout panel
- 5. Laser tuning meter and tune switch
- 6. Prints-plots/min and Print switches
- 7. Normal pushbutton
- 8. Smooth pushbutton
- 9. X10 pushbutton

- 10. Velocity pushbutton
- 11. Velocity switch
- 12. Compensation PPM thumbwheels
- 13. Air compensation table
- 14. Checks 1 switch
- 15. Checks 2 switch
- 16. Units switch
- 17. Direction sense switch





- 1. Printer connector
- 2. Compensation connector
- Timer jacks
  Recorder connectors
- 4. Hecorder connectors
- 5. Laser connector

- 6. Selector switch
- 7. Fuse receptacle
- 8. 115/230 v ac receptacle
- 9. Auxiliary connector
- 10. Air filter retaining screws

Display and Printout, Rear Panel Controls and Connectors