NASA-TM-81454 19800010098

NASA Technical Memorandum 81454

FIBER OPTIC SENSORS FOR MEASURING ANGULAR POSITION AND ROTATIONAL SPEED

Robert J. Baumbick
Lewis Research Center
Cleveland, Ohio

March 1980

SUMMARY

Two optical sensors, a 360° rotary encoder and a tachometer, were built for operation with the light source and detectors located remotely from the sensors. The source and detectors were coupled to the passive sensing heads through 3.65-meter fiberoptic cables. The rotary encoder and tachometer were subjected to limited environmental testing. They were installed on an airbreathing engine during recent altitude tests. Over 100 hours of engine operation were accumulated without any failure of either device.

INTRODUCTION

This effort is part of an overall program to develop more reliable sensors for use in airbreathing engine digital control applications. Two sensors are discussed herein. One is an optical rotary encoder for angular position measurements and the other is an optical tachometer. The sensors, built by Spectronics, Inc. under NASA Lewis sponsorship, do not require electrical power connections at the sensing head. A number of manufacturers have available, optical encoders and tachometers but they require electrical power connections at the sensing head. The sensors built by Spectronics consist of a passive sensor that communicates with the remote electronics box via fiberoptic cable (fig. 1). In the electronics box are the light source and the optical detector. This passive sensor configuration is attractive because of fiberoptic's natural immunity to RFI and EMI generated noise. Also, since there are no electrical connectors, the danger of sparking contacts is nonexistent, and these passive sensors can be used in and around areas containing flammable materials.

Sensors of this type have inherently digital outputs which make them very attractive for use with a digital control because no converters are required. One requirement imposed on the optical rotary encoder and optical tachometer is that the sensor portion be capable of operating reliably in an airbreathing engine environment. Vibrations can be severe while ambient temperatures can reach 244° C.

E-381

HARDWARE

Figure 2 shows a sketch of the rotary encoder and tachometer with electronics box, cables, and connectors. The light source and detectors for the rotary encoder and tachometer are housed in the same box. There are approximately 3.65 meters of cable between the sensors and the electronics box. There are two cables shown going to the tachometer and 10 cables for the rotary encoder. One cable for each sensor is to bring light to the sensor. The other cables return the signal from the sensor to the electronics box where the optical signal is converted to an electrical signal. Each sensor is contained in a 7-cm cube. Each cube has provisions for driving the sensor and for coupling to the fiberoptic cables.

Figure 3 shows the pattern used for the rotary, optical encoder. The rotary encoder disk contains a nine bit word output that is expressed in Gray code. There are 360 codes used such that the resolution of angular position is 1°. The disk rotates with the input shaft, and contains nine circular channels formed by transparent and opaque sections. Light is brought to one side of the disk by an optical cable. On the other side of the disk there are nine channels of optical fibers which receive the light as modified by the disk. Complementary logic is used for the output (light on detector results in zero or low level output and vice versa). The holes for the receiver optical fibers are positioned on the sensor mount as shown in figure 4.

Figure 5 shows the pattern used for the optical tachometer. The disk of the tachometer has only one circular channel. Two optical cables are required. One directs light to the disk, the other carries the modified light back to the detector. The channel coated on the disk has nine transparent and nine opague windows yielding nine pulses/revolution of the shaft.

Both the tachometer and rotary encoder are glass disks into which a pattern was deposited. The method used to produce the patterns on the disk is as follows. First, chrome is evaporated on a glass disk. Photoresist is then applied to the chrome. The pattern is exposed using an emulsion on the glass disk. The photoresist is developed. The exposed chrome is etched away. The remaining photoresist is then cleaned off.

The fiberoptic cables used were purchased from Galileo. The cables are Galite 1000 with original sheath removed and replaced with a high temperature teflon sheath. Each cable is a 212 strand bundle. High temperature epoxy, Eccobond 55, was used to cement the cables into the connectors.

The electronics package encloses one ±12-V power supply, two light sources and 10 signal receiving boards. Two LED's, connected in series, provide light to the tachometer and the encoder. The LED's are Spectronics SPX 2231 and the detectors are Spectronics SPX 2232.

The 10-signal receiving circuit boards are the same for each channel of the encoder and for the tachometer. Figure 6 shows a typical circuit. The circuit is made up of a PIN photodetector, amplifier, and a threshold circuit. The output voltage at E7 is TTL compatible.

ACCEPTANCE TESTS

A rotary indexing table was used for the initial acceptance tests. The encoder output of the electronics box was converted from a Gray code to a three-digit decimal readout. The results of the acceptance tests showed that the indexing table and decimal readout differed by no more than 0.4° for the worst case. Transition points were also checked for the tachometer with the rotary table. All spacings between successive positive transitions or successive negative transitions were in the range of $40^{\circ} \pm 0.3^{\circ}$; that is, each time the tachometer switched from high to low the angular displacement was 40°.

Preliminary environmental tests were conducted under less severe conditions than those specified in the contract because of concern that the sensors might be damaged and thus prevent engine testing. The sensors were subjected to vibration tests. From 0.5 to 50 Hz the disturbance amplitude was 0.045 cm zero to peak. From 50 Hz to 2 kHz the acceleration was kept constant at 1.5 g. The input was sinusoidal. The input was swept over the 0.5 Hz to 2 kHz frequency range in 1 minute and 20 seconds. Each transducer was subjected to three sweeps up and three sweeps down while the output was monitored. The vibrations were applied radially and axially on both transducers.

The sensors were subjected to temperature tests as follows. The temperature was raised to 149° C from room temperature and back again. The sensor was held at 149° C for 10 minutes. After the temperature cycling tests the sensors were soaked at 149° C for 20 minutes. The shaft of each transducer was held fixed. The sensor output was monitored during the tests. The environmental tests did not significantly alter the sensor outputs. After the environmental tests the sensors were checked for mechanical and optical integrity. No signs of increased friction or shaft binding or of signal degradation was experienced for either sensor.

ENGINE TESTS

The two sensors (fig. 7) were installed on an F100 engine in an altitude test cell. The rotary position encoder was installed on the engine to measure rear compressor variable vanes (ECVV). The total angular movement of the RCVV was only approximately 40°. The rotary encoder was changed during the course of the program to assure more than one portion of the rotary encoder disk was used. The tachometer was connected to the hand crank gear on the power takeoff pad. Figures 8 and 9 show the encoder and tachometer mounted on the engine. The vibrations in the areas where the sensors were located exceeded 0.014 cm peak-peak but the exact level was not determined because of failure of the vibration instrumentation. The temperature at the optical sensor locations reached a high of 93° C for some of the runs. Comparison of the optical sensor outputs to reference instrumentation located on the engine showed good comparison between the optical and standard instrumentation. The total time these optical instruments were on the engine was in excess of 100 hours.

CONCLUSIONS

The feasibility of using passive optical sensors for measuring positions and speeds on airbreathing engines has been shown. Although the temperature environment during the engine tests were substantially lower than would be experienced in flight, it is believed that the vibration encountered at the attachment points during the testing was realistic. Since these sensors are resistant to EMI and RFI, digitally compatible and can operate in the engine environment they are good candidates for position and speed measurements on future digitally controlled aircraft engines.

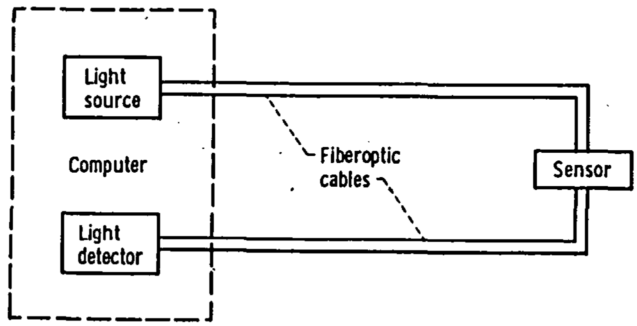


Figure 1. - Passive optical sensor system.

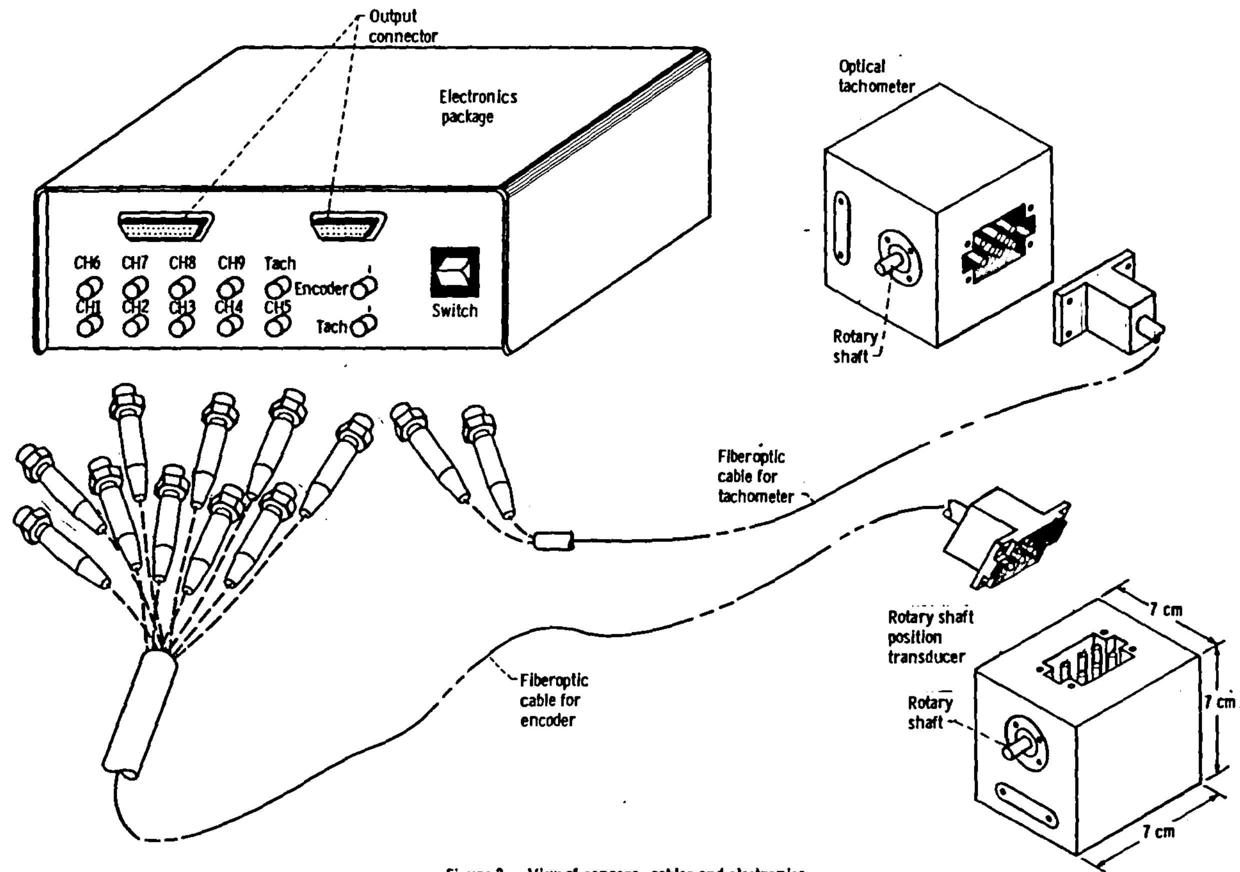


Figure 2. - View of sensors, cables and electronics.

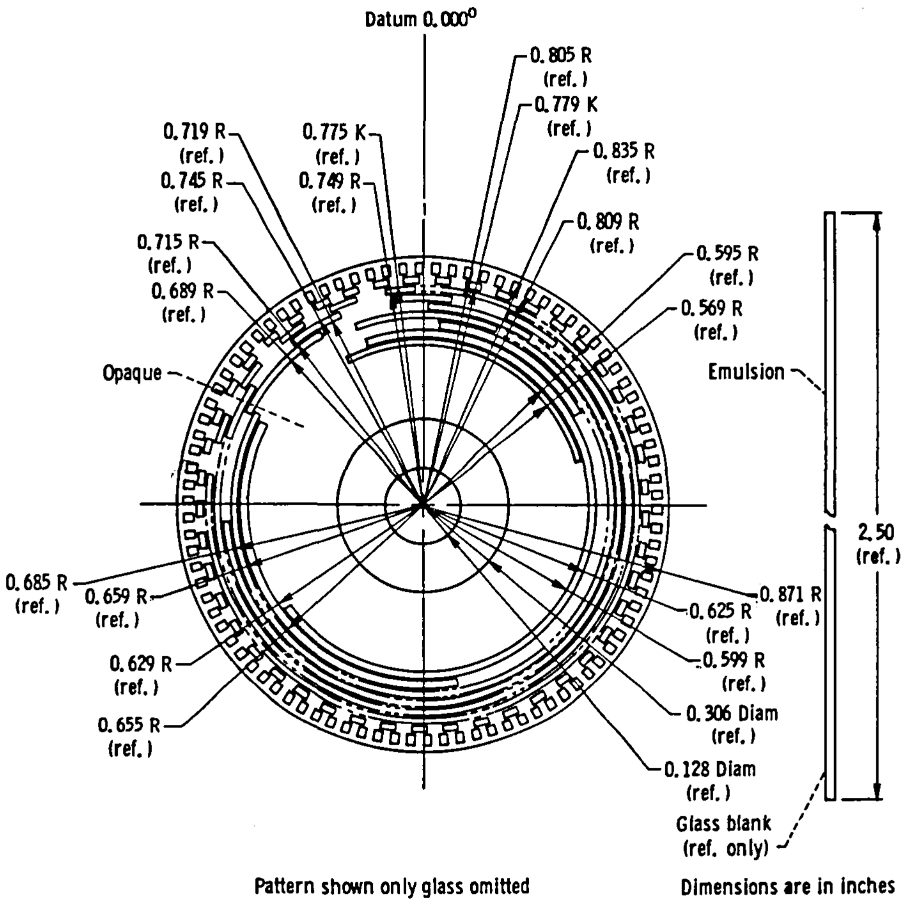


Figure 3. - Rotary position encoder disk pattern.

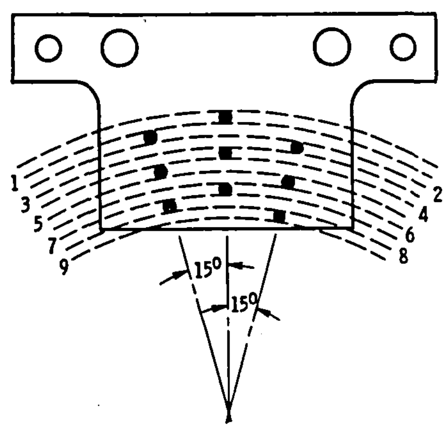
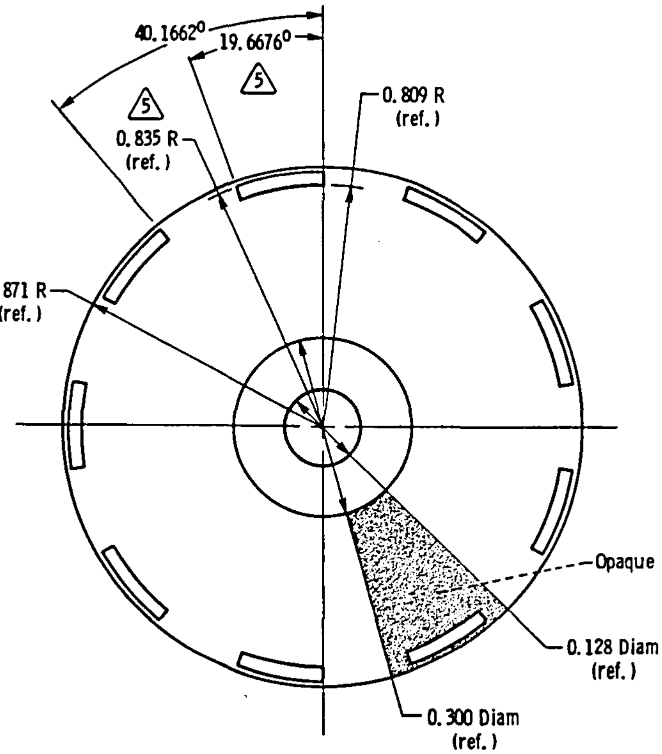


Figure 4. - Hole position on sensor mount for rotary position encoder.



Dimensions are in inches

Figure 5. - Optical tachometer disk pattern.

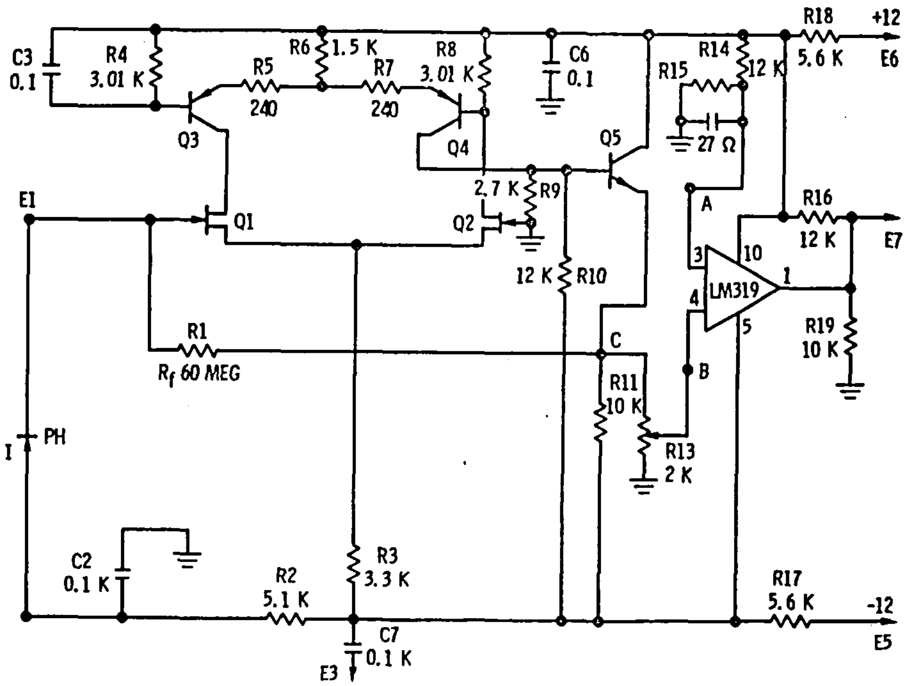


Figure 6. - Circuit diagram.

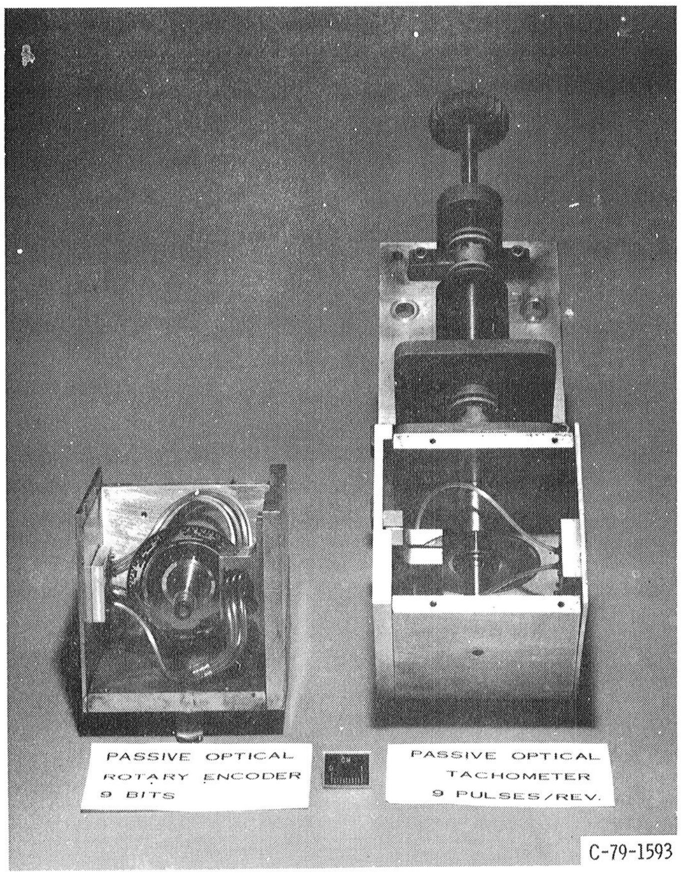


Figure 7. - Optical encoder and optical tachometer.

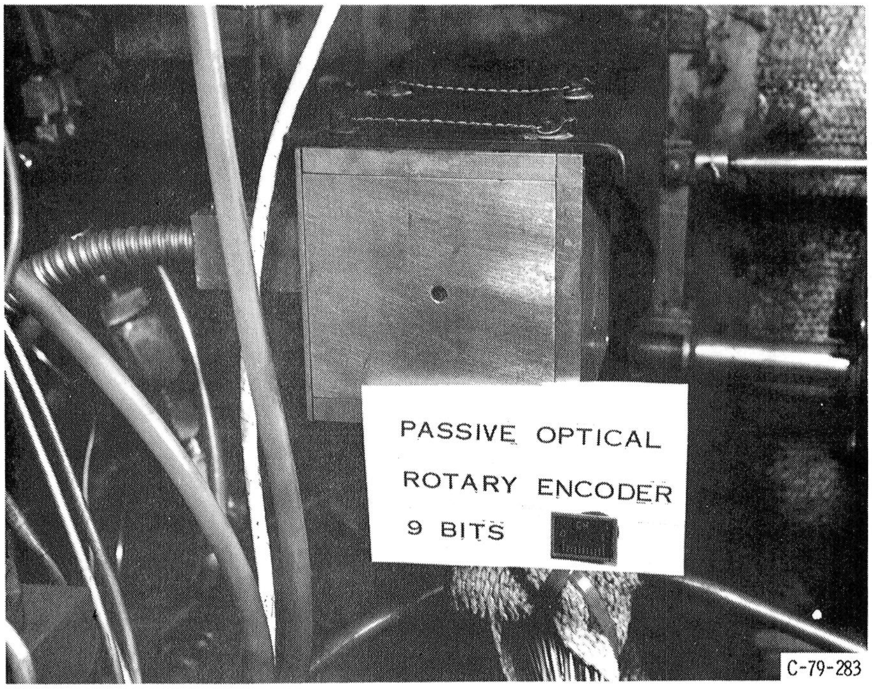


Figure 8. - Optical encoder mounted on engine.

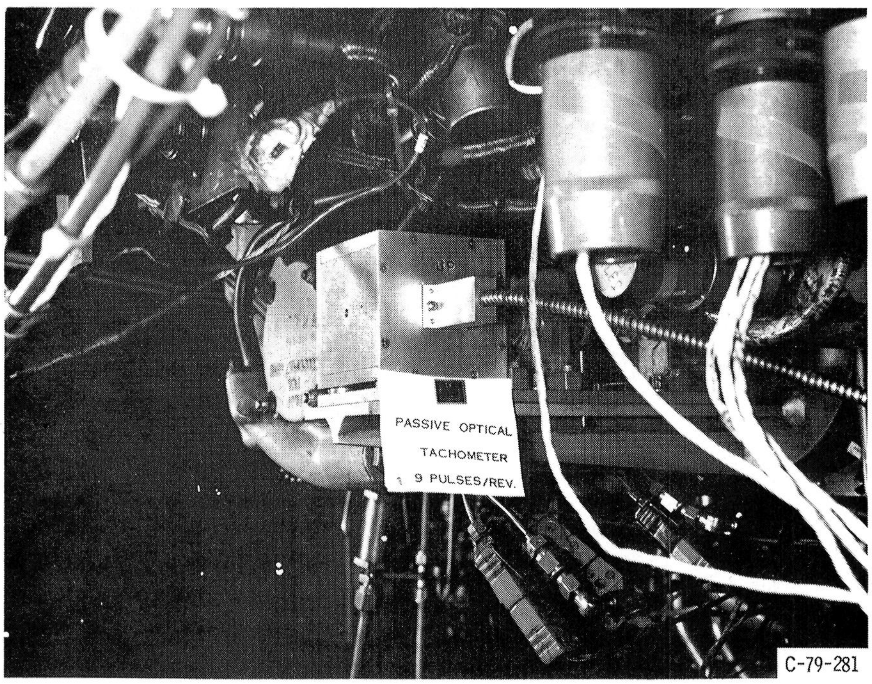


Figure 9. - Optical tachometer mounted on engine.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-81454		

4. Title and Subtitle	5. Report Date
FIBER OPTIC SENSORS FOR MEASURING ANGULAR POSITION AND ROTATIONAL SPEED	March 1980
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Robert J. Baumbick	E-381
	10. Work Unit No.
9. Performing Organization Name and Address	11. Contract or Grant No.
National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Two optical sensors, a 360° rotary encoder and a tachometer, were built for operation with the light source and detectors located remotely from the sensors. The source and detectors were coupled to the passive sensing heads through 3.65-meter fiberoptic cables. The rotary encoder and tachometer were subjected to limited environmental testing. They were installed on an air-breathing engine during recent altitude tests. Over 100 hours of engine operation were accumulated without any failure of either device.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Remote sensors Position sensing Remote optical instrumentation	Unclassified - unlimited STAR Category 35

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161