

alarm circuit gives sufficient advance warning to enable the technicians to go to the voice recorders and change recording disks in time to ensure continuity of recording.

The circuit (see figure) includes a sensor in each voice recorder that closes a switch when the unused space on the recording disk falls below a preset minimum. A sensor switch closure indicates a fault condition in which an audible alarm activates together with a light-emitting diode (LED) for the corresponding fault. Three current steer-

ing diodes make the voltage across, and current through, the audible alarm independent from the number of simultaneous faults. This keeps the alarm tone consistent despite the number of alarms.

For verifying the alarm panel, normally-open push-button switches are wired in parallel with the remote sensor switches. This arrangement decouples the test circuitry from the alarm circuitry, which (1) allows each alarm to be tested without the presence of a fault condition on a voice

recorder, and (2) prevents any failure in the test circuitry itself from disabling an alarm indication when an actual fault condition is present on a voice recorder. Pressing a push-to-test button causes the audible alarm to signal and the corresponding voice recorder LED to light. A green LED is used as a pilot light.

*This work was done by Harold Minuskin of NASA's Jet Propulsion Laboratory and by John Pastor of XteQ, Inc. Further information is contained in a TSP (see page 1). NPO-40150*

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## Optical Sensing of Combustion Instabilities in Gas Turbines

**Engine operation is diagnosed via infrared radiation emitted by exhaust gases.**

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In a continuing program of research and development, a system has been demonstrated that makes high-speed measurements of thermal infrared radiance from gas-turbine engine exhaust streams. When a gas-turbine engine is operated under conditions that minimize the emission of pollutants, there is a risk of crossing the boundary from stable to unstable combustion. Combustion instability can lead to engine damage and even catastrophic failure. Sensor systems of the type under development could provide valuable data during the development testing of gas-turbine engines or of engine components.

A system of the type under development makes high-speed measurements of thermal infrared radiance from the engine exhaust stream. The sensors of this system can be mounted outside the

engine, which eliminates the need for engine case penetrations typical with other engine dynamics monitors. This is an important advantage in that turbine-engine manufacturers consider such penetrations to be very undesirable.

A prototype infrared sensor system has been built and demonstrated on a turbine engine. This system includes rugged and inexpensive near-infrared sensors and filters that select wavelengths of infrared radiation for high sensitivity. In experiments, low-frequency signatures were consistently observed in the detector outputs. Under some conditions, the signatures also included frequency components having one or two radiance cycles per engine revolution. Although it has yet to be verified, it is thought that the low-frequency signatures may be associated

with bulk-mode combustion instabilities or flow instabilities in the compressor section of the engine, while the engine-revolution-related signatures may be indicative of mechanical problems in the engine. The system also demonstrated the ability to detect transient high-radiance events. These events indicate hot spots in the exhaust stream and were found to increase in frequency during engine acceleration.

*This work was done by James R. Markham, David F. Marran, and James J. Scire, Jr., of Advanced Fuel Research, Inc., for Glenn Research Center.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17355.*

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## Crane-Load Contact Sensor

**The decrease in electrical impedance upon contact is used to detect contact.**

*John F. Kennedy Space Center, Florida*

An electronic instrument has been developed as a prototype of a portable crane-load contact sensor. Such a sensor could be helpful in an application in which the load rests on a base in a horizontal position determined by vertical alignment pins (see Figure 1). If the crane is not positioned to lift the load precisely vertically, then the load can be expected to swing once it has been lifted clear of the pins. If the load is especially heavy, large, and/or fragile, it

could hurt workers and/or damage itself and nearby objects. By indicating whether the load remains in contact with the pins when it has been lifted a fraction of the length of the pins, the crane-load contact sensor helps the crane operator determine whether it is safe to lift the load clear of the pins: If there is contact, then the load is resting against the sides of the pins and, hence, it may not be safe to lift; if contact is occasionally broken, then the load is prob-

ably not resting against the pins, so it should be safe to lift.

It is assumed that the load and base, or at least the pins and the surfaces of the alignment holes in the load, are electrically conductive, so the instrument can use electrical contact to indicate mechanical contact. However, DC resistance cannot be used as an indicator of contact for the following reasons: The load and the base are both electrically grounded

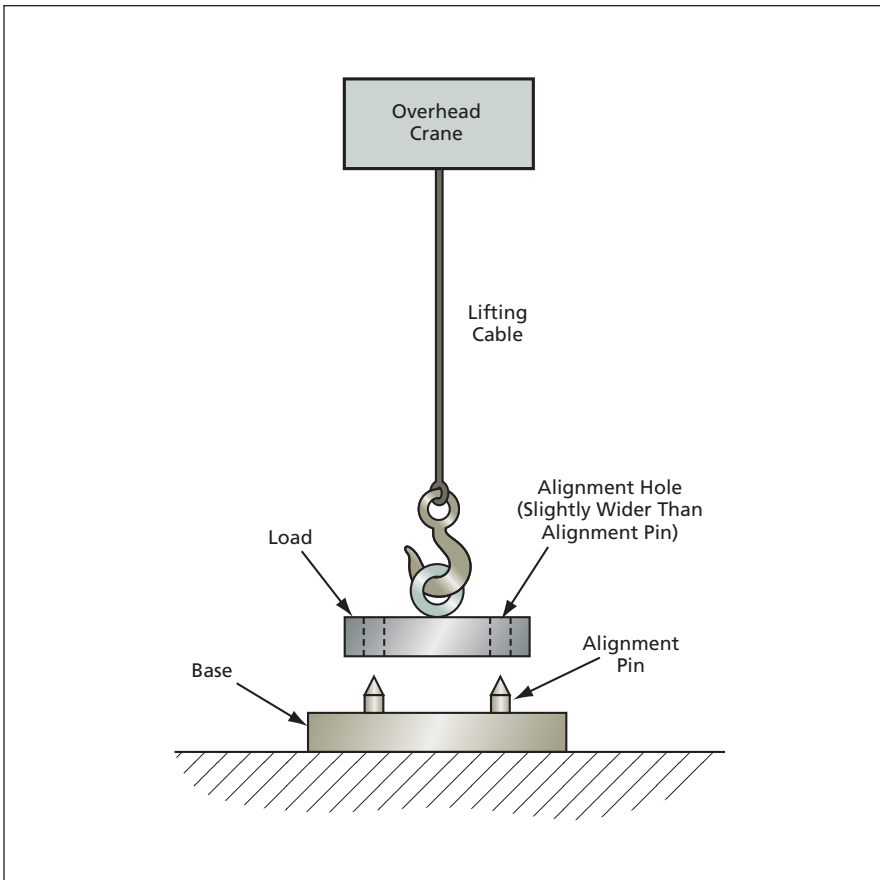


Figure 1. The **Load Must Be Lifted** precisely vertically, or else it will swing when it clears the alignment pins. This means that the crane must be positioned so that during initial lifting, the load does not press sideways against the pins.

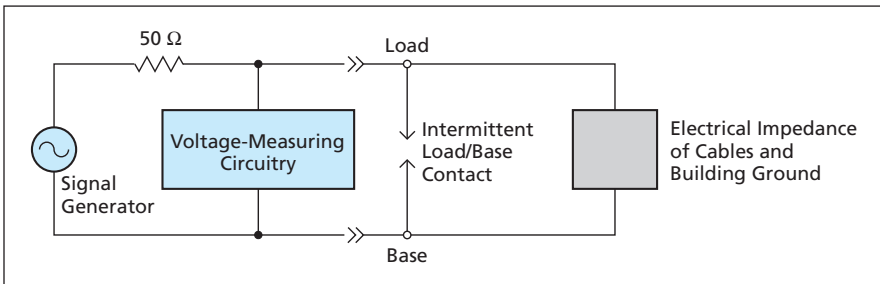


Figure 2. The **Crane-Load Contact Sensor**, shown here greatly simplified for the sake of clarity, measures a voltage related to the base-to-load electrical impedance to determine whether the load and pins are in contact.

through cables (the load is grounded through the lifting cable of the crane) to prevent discharge of static electricity. In other words, the DC resistance between the load and the pins is always low, as though they were always in direct contact.

Therefore, instead of DC resistance, the instrument utilizes the AC electrical impedance between the pins and the load. The signal frequency used in the measurement is high enough ( $\approx 1$  MHz) that the impedance contributed by the cables and the electrical ground network of the building in which the crane and the base are situated is significantly greater than the contact impedance between the pins and the load.

The instrument includes a signal generator and voltage-measuring circuitry, and is connected to the load and the base as shown in Figure 2. The output of the signal generator (typically having amplitude of the order of a volt) is applied to the load via a 50- $\Omega$  resistor, and the voltage between the load and the pins is measured. When the load and the pins are not in contact, the impedance between them is relatively high, causing the measured voltage to exceed a threshold value. When the load and the pins are in contact, the impedance between them falls to a much lower value, causing the voltage to fall below the threshold value. The voltage-measuring circuitry turns on a red light-emitting diode (LED) to indicate the lower-voltage/contact condition. Whenever the contact has been broken and the non-contact/higher-voltage condition has lasted for more than 2 ms, the voltage-measuring circuitry indicates this condition by blinking a green LED.

*This work was done by Robert Youngquist of Kennedy Space Center and Carlos Mata and Robert Cox of ASRC Aerospace. Further information is contained in a TSP (see page 1). KSC-12702*