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DIGITAL FUEL GAGES

Lockheed
service news

A SERVICE PUBLICATION OF
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Cover: An MC-130E o erate by the 834th AGS of the 1st Special Operations Wing, Hurlburt Field, Florida, gets some final touches from SSgt Bruce C. Brege Jr at this year's Volant Rodeo. The back cover shows another view of this premiere international airlift competition, held annually at Pope AFB, N.C.

Focal&in I

AL MILLS

introducing Digital Technology

One of the unique things about the Hercules aircraft is its extraordinary adaptability. It is fair to say that this remarkable airlifter has been undergoing a process of evolutionary development and improvement ever since the first production aircraft came off the line more than 30 years ago.

A recent major update deserves to be noted asaspecial milestone. The new fuel quantity indicating system, which is described in this issue of Service News, represents the first full-scale application of digital technology to a major operating system of the Hercules aircraft.

It is no exaggeration to say that the features designed into this new system offer a quantum leap in fuel quantity indicating system capability.

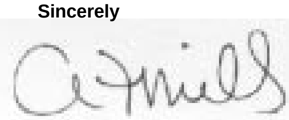
The new system performs the basic function of providing fuel quantity indications in a sophisticated, yet straightforward way. A microprocessor built into each primary fuel quantityindicatorusestheelectrical signals received from the tank units to calculate fuel quantity information, which is then presented on a liquid-crystal display.

But that is just the beginning of the story. The digital indicators are also able to display error codes which show the presence of electrical Or functional discrepancies. The system is capable of discriminating among a wide variety of possible malfunctions, thus offering real assistance to the maintenance technician troubleshooting the cause of a fuel system problem. In addition, the indicators continuously check the integrity of their own internal operations. This ensures accurate and dependable performance at all times.

With its versatility and wide-ranging analytical capabilities, the new fuel quantity indicatingsystem provides an excellent example of the immense promiseof microprocessor-based digital technology in modern aviation.

The digital fuel quantity system is a reality today, but we have only scratched the surface in rhe possible uses of this technology. As research points the way to further applications of digital technology, you can be sure that Lockheed-Georgia Engineering will be on the forefront of the effort to make these advances part of the everyday operating environment of the aerospace industry.

Sincerely



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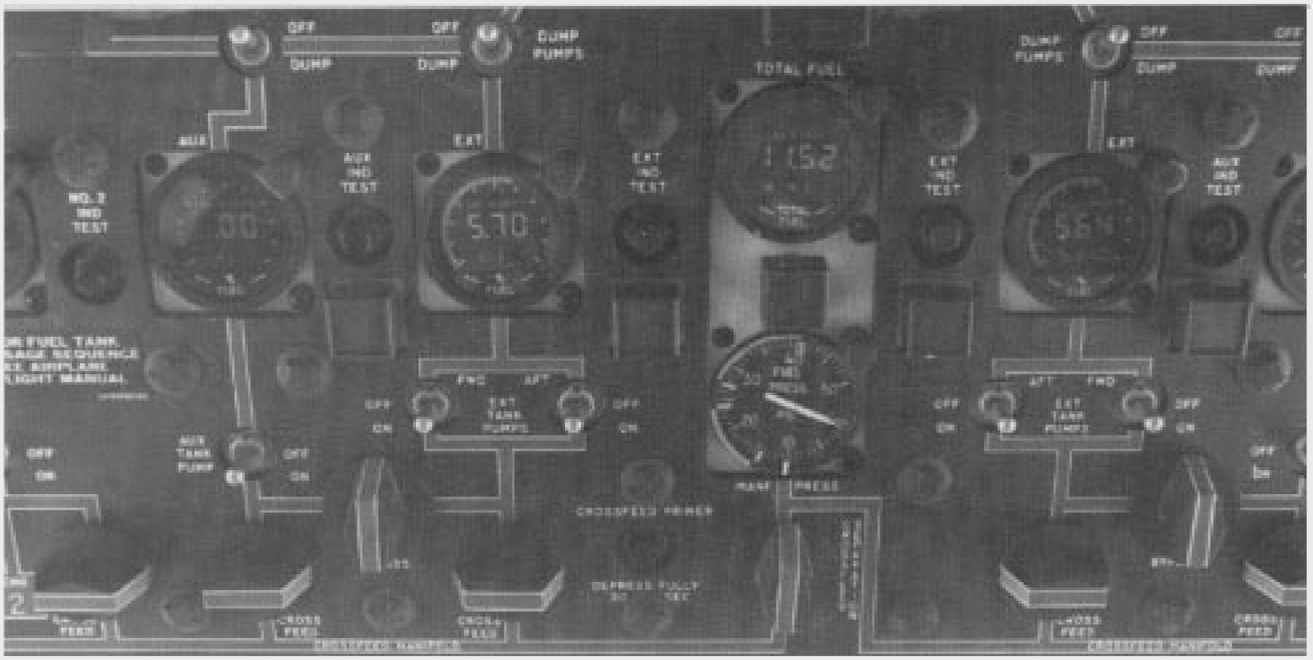

new digital fuel quantity indicating system

by **Floyd** Posey, Field Service Representative
Mark Clark, Design Engineer

DESCRIPTION

Most Hercules aircraft Lockheed serial number LAC 5041 and up are now equipped with a digital, computerized fuel quantity indicating system. This new system, which is manufactured by Simmonds Precision, replaces the analog fuel quantity indicating system gages used on earlier Hercules aircraft and incorporates many advanced features.

The digital system utilizes the existing tank units and associated wiring, and the new gages are physically interchangeable with the earlier analog servomechanical fuel gages (some minor wiring and connector changes are required.) However, it is not possible to mix the two types. All fuel gages on an aircraft must be of the new computerized type or they must all be of the earlier analog type.

SYSTEM COMPONENTS

Primary **Indicators**

There are eight identical primary indicators, all the same part number, which are used in the flight station in place of the earlier gages. Each primary indicator is a self-contained, computerized fuel gage that independently measures tank unit and compensator capacitance values, computes fuel quantity, and displays the data in both digital and analog formats. Tank identification is determined by the arrangement of jumper wires in the plugs which connect the individual indicators to the aircraft wiring.

Empty calibration is provided by a rear-mounted adjustment (see Figure 1). Since the required span from empty to full is programmed into the indicator memory, no full adjustment is necessary and no provision for this adjustment has been included.

Figure 1. Empty calibration adjustment

Repeater Indicators

The fuel gages on the SPR panel (Figure 2) are slaved to the primary units in the flight station. These repeater indicators are simpler and less costly than the primary indicators. Each repeater indicator receives digital data from the associated primary indicator when the refueling relay is activated. Digital data transmission ensures agreement between the primary and repeater displays. The repeater indicators display the data in a manner identical to the primary indicators.

Totalizer

The totalizer unit that is part of the analog system is not used with the new digital computerized indicators. The summation of the primary indicators is performed in the totalizer indicator, and since digital data transmission is used, no calibration is required for the totalizer indicator or repeater indicators.

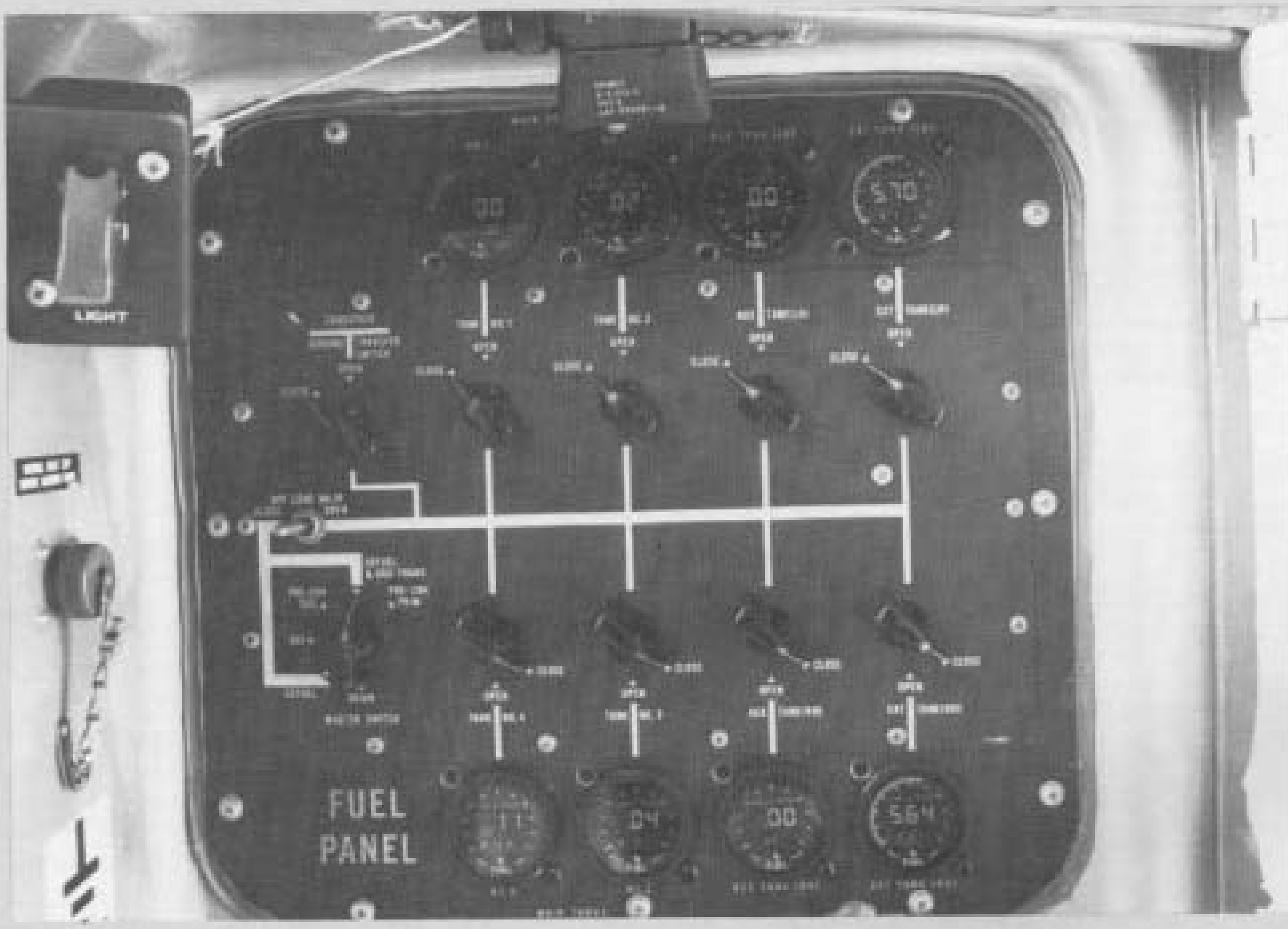

Figure 2. SPR panel

Figure 3. Primary indicator

Varistor and Indicating Fuse

Like other precision electronic components, the **microprocessors** that are incorporated in each primary indicator and the totalizer must be protected from voltage surges. On the Hercules aircraft, this protection is provided by a surge suppression device (varistor) connected between the AC instrument and fuel control bus and the airframe (ground). A surge suppression protection indicating fuse is located on the pilot's circuit breaker and fuse panel to indicate a shorted failure of the varistor.

Should such a failure occur, the fuse blows, electrically opening the circuit between the bus varistor and ground, thus disconnecting the shorted varistor from the bus. If this fuse blows in flight, no action is required by the flight crew. However, at the post-flight inspection, the ground maintenance personnel should check the varistor to determine if it is shorted, and replace it and the fuse if necessary A spare fuse is provided in the electrical spares box above the navigator's table.

FUEL QUANTITY DISPLAY

Digital/Analog Format

This new system measures the signals sent by each group of fuel probes (tank units) independently, and displays fuel quantity information in both digital and analog formats. The digital format consists of three numerics, a decimal point, and a multiplier on a liquid crystal display (see Figure 3). The analog format consists of a 51-segment circular bar graph, which represents the range of 0 to 100 percent of maximum fuel quantity (at maximum fuel density) in 2-percent increments, with associated reference points at IO-percent increments.

Codes

A tank code identifying the fuel tank to which a particular gage is connected appears at the bottom left of the indicator display. The main tanks are identified as Ml, M2, M3, and M4. The external tanks are identified as El and E2. The auxiliary tanks are identified as Al and A2.

Error codes (E, EO - E9) which report various types of system or indicator faults appear at the bottom right of the indicator display.

Note that the codes for the external tanks and certain error codes are identical except for position on the display: tank codes El and E2 appear at the left of the display, while error codes El and E2 appear at the right of the display.

Indicator Lighting

Lighting for the digital fuel quantity indicators is provided by 28-VDC post lights. The indicator post lights are controlled independently from other overhead panel lights by a dimmer located above the copilot's upper circuit breaker panel.

SELF-TEST FEATURE

The built-in test (BIT) for the primary indicators verifies that the display, and the compensator, and the tank units are operational. In addition, the test feature isolates and displays common fuel indicating system faults, which greatly facilitates system maintenance and troubleshooting.

Each primary indicator responds to a test switch which causes the indicator display to decrease toward zero. Upon release, the indicator displays the following:

- All segments ON for approximately 4 seconds.
- All segments OFF for approximately 4 seconds.
- Any stored error codes that have occurred since power-up (see Figure 4).

Any detected system faults are annunciated on the error code display upon completion of the indicator test sequence.

Testing a primary indicator will also trigger a test sequence of the totalizer indicator or the associated repeater indicator, whichever is in use at the time. The test sequence for the totalizer indicator and repeater indicators is as follows:

- Fuel quantity display decreases toward zero.
- All segments ON for approximately 4 seconds.
- All segments OFF for approximately 4 seconds.
- Return to normal display.

SYSTEM MONITORING CAPABILITY

Because the capacitance values of the compensator and the combined tankunits are measured independently, the indicator distinguishes between a faulty compensator and wiring, and the tank units and wiring. Furthermore, the indicators are able to substitute appropriate values mathematically to correct for defective compensators or defective low impedance compensator wiring. This enables the system to provide a safe, usable fuel quantity indication even in the presence of a problem.

Figure 4. Indicator self-test display

IMPROVED RELIABILITY

The Simmonds computerized fuel quantity gaging system uses a 5.68 KHz signal to excite the tank units and compensators. The use of this high frequency significantly increases the ratio of resistance to capacitive reactance over that of the typical 400-Hz system. This makes the new indicating system much less susceptible to inaccuracy caused by the effects of fuel tank contaminants. The number of fuel gaging problems is therefore greatly reduced.

SYSTEM ADVANTAGES

In summary, the advantages of the new digital computerized fuel quantity indicating system are:

- Solid-state components.
- Liquid crystal display.
- High-frequency excitation.
- Built-in test feature.

- Modular packaging.
- Common unit inventory.

The Simmonds Precision design achieves maximum flexibility by allowing the built-in microprocessor to perform all indicator functions. Furthermore, new features can be implemented without hardware changes.

TROUBLESHOOTING

Troubleshooting the fuel quantity indicating system will in most cases involve the use of the GTF-6 test set or equivalent to verify continuity of flight station to tank wiring, in-tank wiring, and the condition of the tank units and compensators.

Note that &troubleshooting activities involving the fuelquantityindicating system, including the connection and use of the GTF-6 test set, must be carried out in strict conformity to the safety precautions and other procedures specified in the applicable authorized maintenance manuals.

ERROR **CODE ANALYSIS**

The BIT features incorporated in the Simmonds Precision digital fuel quantity indicators provide flight crews and ground maintenance personnel with valuable assistance in accurate troubleshooting of fuel quantity indicating system problems. These new indicators reduce downtime and maintenance costs by analyzing the fuel quantity indicating system from the fuel tank to the flight deck and displaying error codes which indicate common faults. The key to obtaining the maximum benefit from this information is, of course, correct interpretation of the indications.

PRIMARY INDICATOR

The heart of the new digital indicating system is the primary indicator for each tank. The BIT for the primary indicator verifies the operation of the display, checks for three separate compensator faults, four tank unit faults, indicator calibration failure, and two levels of internal indicator failure.

Table 1 provides an explanation of various primary indicator fuel quantity displays and error messages, and the action that is recommended for each situation. Note that in the tables and the following discussion the abbreviation lo-Z is used for low impedance and hi-Z for high impedance.

Table 1. Primary Indicator Error Codes

Code	Fuel Qty Display	Explanation	Recommended Action
E0	Zero with error code	Open or missing tank unit assembly	Verify continuity of in-tank wiring to each tank unit. Check hi-Z isolation from shield.
El	Error code with normal display at reduced accuracy	Tank unit electrical leakage	Check condition of each tank unit.
E2	Zero with error code	Hi-Z open or shorted	Check hi-Z from indicator to tank, lo-Z wires to tank units, and compensator.
E3	Error code with normal display at reduced accuracy	Compensator unit lo-Z open or shorted	Check lo-Z wire from indicator to compensator.
E4	Zero with error code	Tank "nit open or shorted	Check lo-Z *wire* from indicator to tank units.
E5	Error **code with** normal display at **reduced accuracy**, or zero with error code	Compensator fault	Check condition of compensator. Check hi-Z shield continuity.
E6	Zero with error code	Shorted tank unit fault	Check condition of each tank unit. Check hi-Z shield continuity Check for water or ice in tank units.
E7	Error code with normal display at reduced accuracy	**Compensator** unit electrical leakage	Check condition of compensator. Check compensator hi-Z shield continuity
E8	Zero with error code	Indicator fault	Replace indicator.
E9	zero or normal display with error code, reduced accuracy	Internal calibration fault	Replace indicator.
Blank	Blank	Indicator micro-processor fault or loss of power	Verify 115V at connector. Replace indicator if required.

Note: Use only authorized equipment and procedures in troubleshooting the fuel quantity **indicating system.**

PRIMARY INDICATOR CODES

Error Code EO - Open or Missing Tank Unit Assembly

The capacitance value of the tank units is known to have a specific value when the tank is empty. If one tank unit or a group of tank units is disconnected from the group, the measured tank unit total capacitance will be less than the expected value.

Error code EO is indicative of an in-tank wiring problem. The recommended maintenance action is to verify the continuity of the in-tank wiring, and to check hi-Z isolation from airframe or shield.

Error Code El - Tank Unit Electrical Leakage

The resistance of the tank units installed in each tank is periodically checked by means of an automatic testing procedure carried out by the indicator microprocessor. When excessive current leakage is detected, error code El is displayed.

When this condition is present, fuel quantity continues to be displayed, but with 2.0 percent or less error imposed by electrical leakage. Error condition El indicates an in-tank condition. The recommended maintenance action is to drain the tank and check the tank units for contamination.

This error code is sometimes caused by a two-point ground on the shield, allowing circulating currents.

Note that if the measured resistance is severely out of limits, or a shorted tank unit is present, error code E6 will be displayed.

Error Code E2 - Hi-Z Open or Shorted

Both tank units and the compensator share a common hi-2 signal line. If an in-range signal is not detected on the hi-Z signal line after normal excitation of both the tank unit and the compensator, the hi-Z signal line is either open, shorted to shield, or shorted to ground (airframe). When this condition is present, the fuel quantity display will go to zero.

Error code E2 normally indicates a wiring problem in the coaxial wire and connectors in the aircraft wiring harness between the indicator and the tank. The recommended maintenance action is to check the hi-Z signal wire to airframe and hi-Z to shield. Check for hi-Z continuity, indicator to tank unit. Error code E2 is displayed when tank unit lo-Z and compensator lo-Z are both open at the same time, or when there is an open cable connector in both lines.

Error Code E3 - Compensator Lo-Z Open or Shorted

Since the indicator microprocessors independently excite the compensators and measure both the excitation and the return signal, it is possible to identify specific wiring problems with compensator lo-Z wiring. If the lo-Z signal line is open, a return signal will not be detected. If the lo-Z signal line is shorted to ground, the detected excitation signal will be zero.

When these conditions are present, fuel quantity will continue to be displayed and the indicator microprocessor will use a stored value equivalent to a nominal fuel dielectric constant in place of the measured compensator value.

Error code E3 indicates wiring problems. The recommended maintenance action is to check the wiring harness from the indicator to the tank (specifically, the compensator lo-Z signal wire). Verify continuity and isolation from ground.

Error Code E4 - Tank Unit Lo-Z Open or Shorted

Each indicator microprocessor independently excites the tank unit sensors and detects an open or short in the tank unit excitation line similar to error code E3. When this condition is present, the fuel quantity display will go to zero.

Error code E4 indicates an open or short on the lo-Z signal line to the tank units.

Error Code E5 - Compensator Fault

Each compensator is designed to measure a maximum sensor value. If themeasured valueexceeds the maximum value, error code E5 is displayed.

Error code E5 is displayed if conductivity across the compensator is high enough to cause a change of more than approximately 25 percent **(gage** accuracy is still within 2.9 percent) in K -1, which represents the dielectric constant used to calculate the fuel mass.

When this condition is present, fuel quantity will continue to be displayed and the indicator microprocessor will use a nominal stored value for K -1.

Error code ES indicates foreign matter, water, ice, or excessive contamination in the compensator. The recommended maintenance action is to check the fuel for contamination. If no problemis found, thencheck hi-Z shield continuity and the hi-Z shield to ground. If the shield is okay, physically check the condition of the compensator. Note that even if the fault is cleared, once E5 is set, it may take up to 30 seconds to clear.

Error Code E6 - Shorted tank unit

The tank units are designed to **a** specific capacitance range. If the design capacitance range is exceeded, E6 is displayed. E6is also displayed if conductivity hi-Z to lo-Z is high enough to cause more than 2.0 percent error at empty. When this condition is present, the fuel quantity display goes to zero.

Error code E6 indicates tank unit failure, or drops of water or ice between tank unit tubes. The recommended maintenance action is to check the condition of the individual tank units by test set or inspection. If the tank units check out correctly, test hi-Z shield continuity and ground isolation, and test for stray capacitance hi-Z to IO-Z.

Error Code E7 - Compensator Leakage

The indicator microprocessor for each tank measures the exact extent of resistive contamination in the compensator by periodically using a different excitation frequency and comparing the result with measurements made at the normal excitation frequency. Excessive compensator current leakage will cause error code E7 to be displayed.

When this condition is present, fuel quantity continues to be displayed. If the leakage of current is large enough to cause a significant error in fuel quantity determination, the indicator microprocessor will use a nominal stored value for K -1 in place of the measured compensator value.

Error code E7 indicates that water or other impurities are building up in the sump area where the compensator is located. The recommended maintenance action is to check the fuel for contamination and the condition of the compensator. Check also for an open hi-Z shield to compensator.

An uncovered or partially covered compensator may cause an error code E7. If the fuel level in a given tank is less than 20% of that tank's maximum, an E7 error code may occur. This is considered normal operation. At the start of refueling an empty tank, E7 may display until the compensator is fully covered.

Error Code ES - Indicator Internal Failure

In addition to the detection of system faults, each indicator checks its own internal functional elements. Error code ES reports internal failure of the indicator. The recommended action is to replace the indicator.

Error Code E9 - Internal Calibration Fault

The self-calibration circuitry is continuously checked. If a fault occurs which causes a nonlinearity in the signal processing circuitry or a failure of the system reference elements, E9 will be displayed.

Error code E9 indicates an indicator failure. The recommended maintenance action is to replace the indicator.

Blank Display - Indicator Microprocessor Fault

The circuit is designed so that if the indicator microprocessor fails the display will blank. The maintenance action is to check that power is correctly applied to the indicator. If power is normal, replace the indicator.

MEA0 **Displayed and No Error Code**

The indicator is unable to perform tank ID (identify its associated tank). Check for good plug connection and wiring. If they check out correctly, replace the indicators.

REPEATER INDICATORS

The repeater indicators continuously conduct BIT and display appropriate error codes for detected failures. BIT, including a display test, is also activated when the primary indicator is tested by remote test switch.

The BIT features, recommended maintenance actions, and display status during the error conditions for the repeater indicator are summarized in Table 2:

Table 2. Repeater Indicator Error Codes

Fuel Qty Display	Explanation	Recommended Action
Zero with error code	Open or missing digital input	Verify correct operation of primary indicator. Check wiring between primary and repeater indicator.
Follows primary indicator	Primary indicator is displaying error code	Check primary indicator.
Blank	Indicator failure or loss of power	Verify 115v at connector **Replace** indicator if required.

Note: IJse only authorized equipment and procedures in troubleshooting the fuel quantity indicating system.

REPEATER INDICATOR CODES

Error Code E0 - Open or Missing Digital Input

Error code EO is displayed whenever the digital signal from the primary indicator is not being received. A primary indicator may be inoperative, or a wiring problem may exist between the indicators. A primary indicator error code E3, compensator lo-Z fault, may also cause this error in the repeater indicator.

Error Code E - Received Primary Indicator Error

Error code E does not indicate an error within the repeater indicator. It does show that an error code from a primary tank indicator has been received, indicating that a problem is being reported by that indicator.

Blank - Indicator Failure

The entire display is blanked when there is a major failure of the indicator, which indicates either total failure of the indicator microprocessor or the power supply, or the total failure of the liquid crystal display.

TOTALIZER INDICATOR/SUMMATION UNIT

The BIT features, recommended maintenance actions, and display status during the error conditions for the totalizer indicator and totalizer summation unit are summarized in Table 3.

Table 3. Totalizer Indicator Error Codes

	Fuel Qty **Display**	**Explanation**	**Recommended** Action
	Total fuel **quantity** display minus the fuel quantity of the tank associated with the EO error code	Open/missing digital input	Verify correct **operation** of primary indicators. Check wiring between primary and totalizer indicators.
	Follows primary indicator	Primary indicator is displaying error code	Check primary indicator.
Blank	Blank	Indicator failure or loss of power	Verify 115V at connector. Replace indicator if required.

Note: Use only authorized equipment and procedures in troubleshooting the fuel quantity indicating system.

TOTALIZER INDICATOR CODES

Error Code EO - Open or Missing Digital Input

Error code EO is displayed whenever the digital signal from the primary indicator is inoperative. A primary indicator error code E3, compensator lo-Z fault, may also cause this error code in the totalizer.

Error Code E - Received Primary Indicator Error

Error code E does not indicate an error within the totalizer indicator. It does show that an error code from a primary tank indicator has been received, indicating that a problem is being reported by that indicator.

Blank - Indicator Failure

The entire display is blanked when there is a major failure of the indicator, which results from total failure of the indicator microprocessor or the power supply, or the total failure of the liquid crystal display.

AUTOMATIC PRECISION CALIBRATION SYSTEM

by **Terry James,** Production Liaison Engineer, Senior

The increasing sophistication of electronic test equipment technology has made it impractical to train individual technicians on the calibration verification requirements for every piece of equipment sent to the metrology lab.

Contributing to the problem is the fact that while test equipment is becoming more complex, it is also becoming more reliable. The technician in the metrology lab is therefore unlikely to see the equipment very frequently, which adds to his difficulty in staying current on all requirements.

The Practical Solution

The use of automatic test equipment within the metrology lab offers a practical solution to the need for accurate, methodical, and consistent testing with minimum training. Automatic testing offers many advantages over manual testing:

- Convenient organization of a series of tests.
- Fast test setup and execution.
- Data logging of test results for easy comparison with earlier tests.
- Repeatability, independent of the operator.

PN 3402854-l
Automated Precision Measurement
Electronics Laboratory

Enter APMEL

To meet these requirements, Lockheed-Georgia Company has designed and built the Automated Precision Measurement Electronics Laboratory (APMEL). APMEL is an automated test and calibration system tailored to provide the user with the capability to calibrate the test equipment. used in connection with aircraft maintenance with a high degree of precision.

The hardware employed in this system is off-the-shelf laboratory standard, produced and supported by the major equipment manufacturers. The software is in a high-level language which permits the user to modify, revise, or procure programs to fit his changing needs.

APMEL supports most general-purpose test instruments. It has been specially designed to permit the addition of both hardware and software to meet the specific needs of the individual customer.

Multiple Instruments

The system makes use of the following programmable stimulus or measurement instruments: function generator, digital multimeter, scope calibration generator, AC and DC calibrator, audio analyzer, measuring receiver, RF signal generators, and rubidium oscillator.

Controller with Software

The controller is the heart of the system. The controller is fundamentally a computer which tells the instruments what to do, collects the results, and processes them. It is equipped with a genera-purpose interface bus (GPIB) port capable of communicating with as many as 28 other instruments; it also contains two RS-232-C interface ports for data communications with items such as terminals, printers, or other computers. The controller is equipped with a magnetic tape drive for program and data storage and 512K bytes of memory.

These features make the controller a very flexible and powerful device, capable of processing complicated programs quickly and accurately. At the same time, it is easy to use, and assists the operator with simple step-by-step instructions illustrated by color graphics displays.

Computer Peripherals

An ink jet printer has been provided to produce a hard copy printout of each test run. The printout includes test item performance versus programmed acceptance limits, and a pass/fail status for each calibration point. The record allows the user to develop a historical data file on each piece of equipment tested.

Keyboard

A keyboard enables the user to send commands or information to the system. The keys include ASCI1 upper case, lower case, and control characters, BREAK and ERASE keys, a 14-key numeric keypad, four special function keys, and eight programmable function keys.

Display

A display provides the user with instructions for setup and operation of the system in both text and graphics. It provides a review of intermediate results and monitors system operations. The terminal can display 64 distinct color mixtures. Up to 16colors can bedisplayed simultaneously in the graphics area, with an additional 8 colors in the text area. Color enhances thevisual impact and the information content of both graphics and text.

System Interface

The entire system is mounted in a single three-bay cabinet, including a front-mounted work bench (20 inches by 5.5 feet). All electrical connections are made within the cabinet for thecontroller, measuring instruments, and peripherals.

The measuring instruments are connected on two separate GPIBs to the controller. One bus contains the meter and oscilloscope calibration equipment and the other bus contains the RF instruments. These buses and the instrument interfaces allow connection of the system components to the controller.

The application software which controls the system and provides instruction to the operator is supplied on tape cassettes for each item of equipment to be calibrated.

For More Information

If you would like additional technical or procurement information about the PN 3402854-l Automated Precision Measurement Electronics Laboratory, please direct your inquiries to the Manager, Supply Sales and Contracts Department at the following address.

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Supply Sales and Contracts Department
Dept. 65-11, Zone 451
Marietta, Georgia 30063
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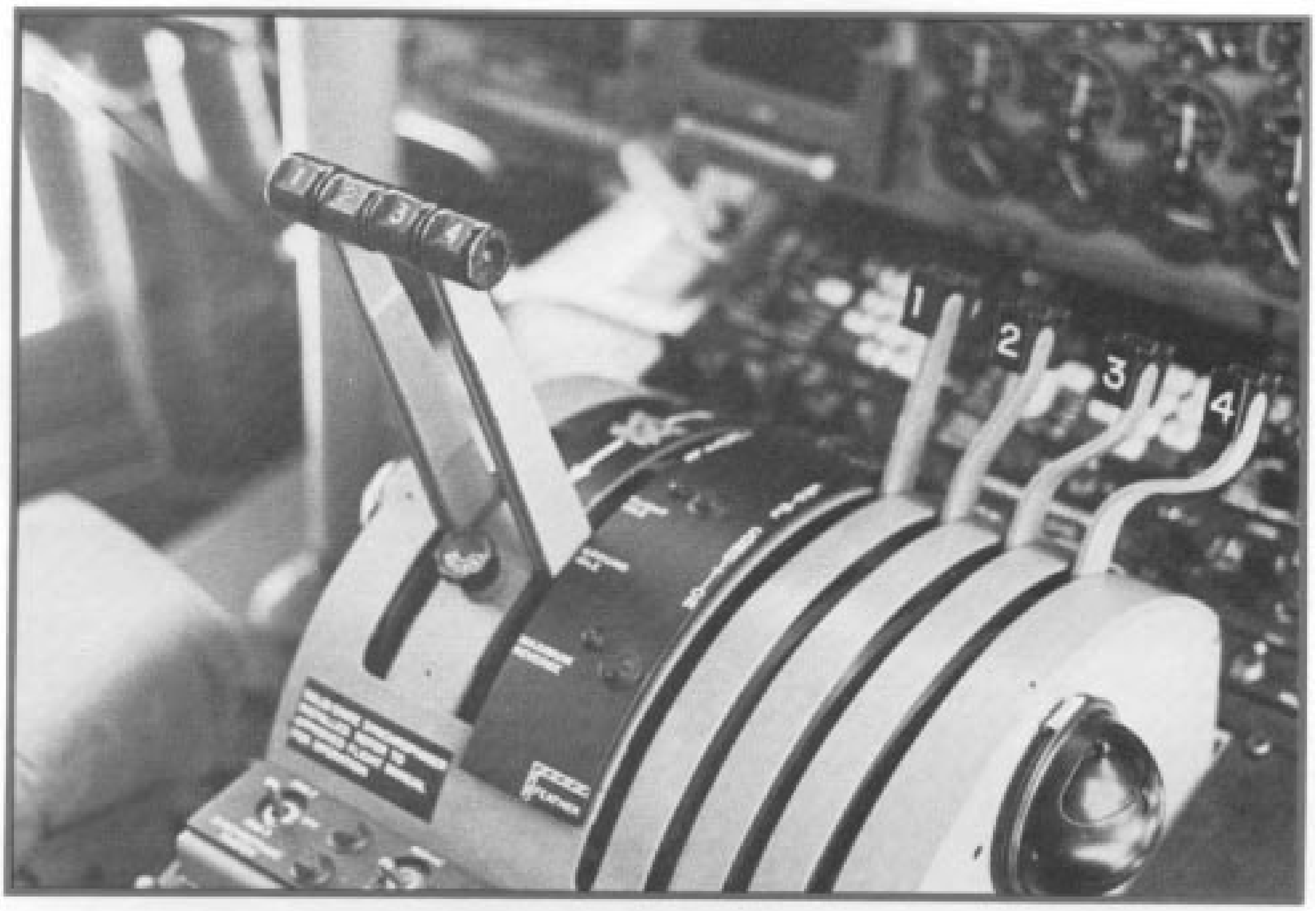


vibration in engine controls

by G.T. **Walker,** Field Service Representative

Vibration with a frequency approximately equivalent to propeller RPM can appear in the throttle or condition levers during flight. When this happens, it is usually isolated to the controls of one engine. The vibration may manifest itself in the throttle, the condition lever, or in both at the same time. This is not an uncommon occurrence and should not be considered a safety of flight item; nevertheless, vibration in engine controls should always be investigated.

Note that an out-of-balance condition in the engine occurs at such a high frequency that it is usually not detectable by the flight crew. An unbalanced propeller, on the other hand, will cause a detectable movement of the nacelle and possibly some other airframe components.

The causes of engine control lever vibration can be, but are not limited to, one or more of the following:

- Worn gimbal bushings.
- Improper engine controls cable tension.
- Worn control pulley bearings and rod ends.
- Worn clutch and clutch bearings at engine firewall quick disconnect.
- Worn attaching hardware in the engine control system.
- Improper propeller phase angle setting.
- Sagging aft engine mount.

With these possible causes in mind, a logical sequence of corrective actions that begins with the easiest to accomplish and progresses to the more difficult and time-consuming should be pursued. The first step should be to verify that the tension on the power plant control cables, both in the airframe and in the nacelles, is within the tolerances specified in the authorized maintenance manual. Pay particular attention to the readings between opposing cables. Where appropriate, they should be as nearly equal as possible.

Worn gimbal bushings are another common cause of controllever vibration. Check gimbal bushings shown in Figure 2. At the same time, check pulley bearing PN PlOK. If any wear is evident, replace all the affected parts.

The clutches and clutch bearings at the firewall quick disconnect (shown in Figure 3) are often overlooked during inspection. A slight amount of wear on either the clutch or clutch bearing can cause control lever vibration.

Improper propeller phase angle settings can also cause control lever vibration. The inboard engines are more frequently affected by propeller phase angle misadjustment than the outboard engines. The severity of vibration is determined by the amount of error in phase

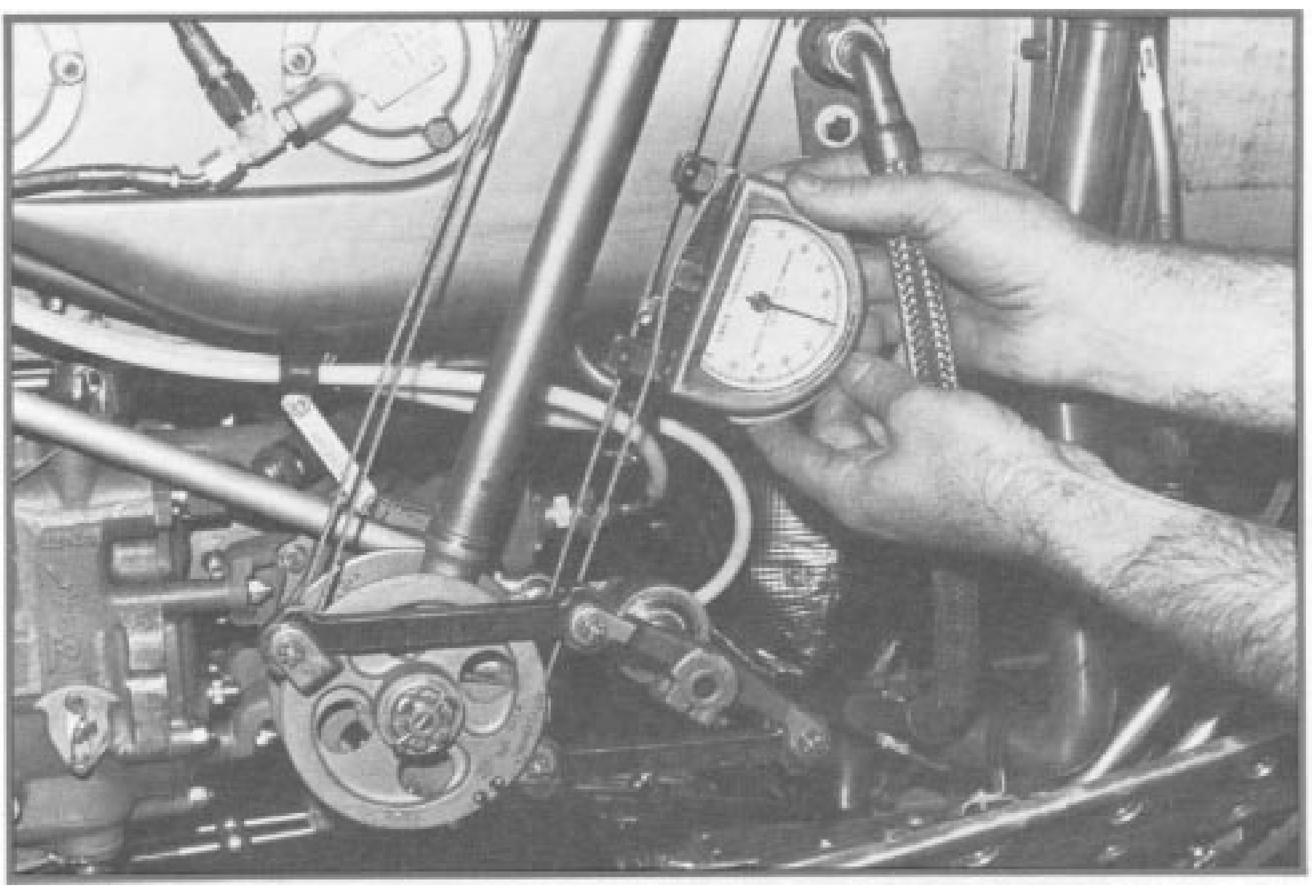


Figure 1. Checking cale tension

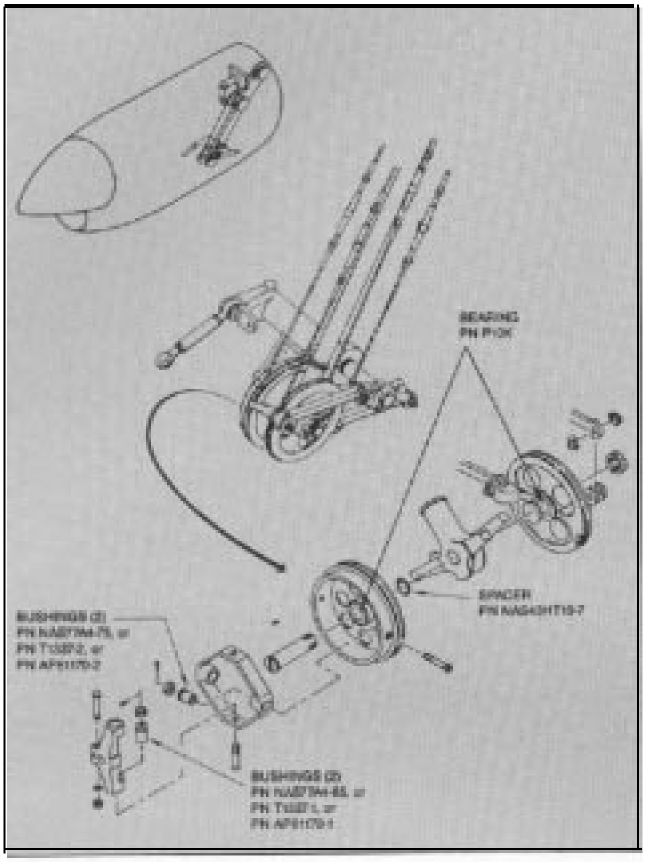
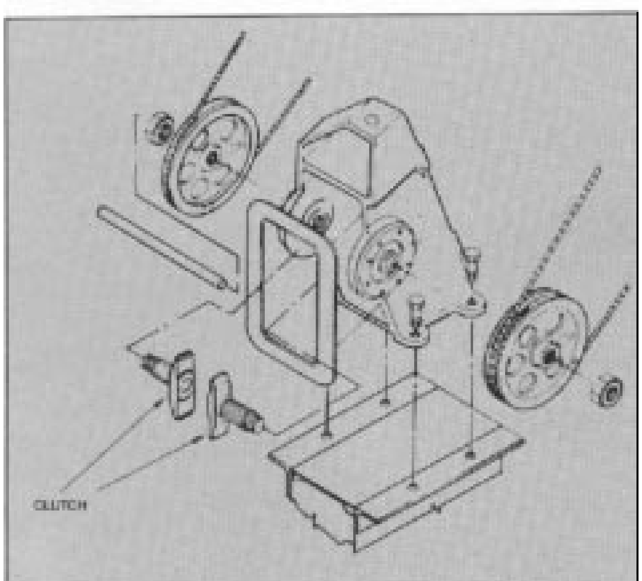


Figure 2. Throttle and condition lever gimbal assembly.

angle setting in the tube type synchrophaser. Note that it is not possible to make field adjustments of phase angle settings on the solid-state synchrophaser, but these adjustments are possible on the tube type synchrophaser, using the proper equipment.



-*Figure 3.* Engine controls firewall quick disconnect.

A final step is to check the rear engine mount. Some maintenance organizations routinely replace rear engine mounts when vibration problems are reported, but this is not necessarily a cure-all. If available, use a Lord Corporation PN LT27 tool to check the mount for permanent set. Defective rear engine mounts have been the cause of vibration felt in the controls in some instances; however, experience has shown that replacement of engine mounts-in particular good ones-does not always solve the problem. More often than not, a combination of factors is involved. A systematic approach that takes all of the possible causes of control lever vibration into consideration is therefore likely to solve the problem with the least expenditure of time and effort.

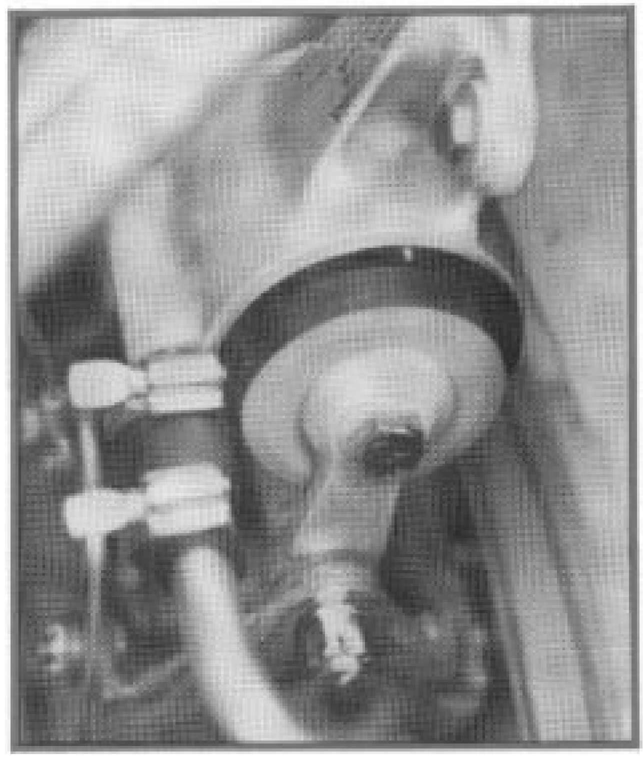


Figure 4. Rear engine mount.

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