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P-3 FUEL QUANTITY INDICATING SYSTEM

FRONT AND BACK COVERS No. 11 Squadron Royal Australian Air Force is located near Adelaide in South Australia. The Squadron is well known to American, British and New Zealand maritime bases in the Pacific and Southeast Asia through participation in SEATO and Operational Readiness Exercises. Recent exchange tours of duty by RAF, USN and Canadian Armed Forces officers have given No. 11 Squadron an international flavor.

The Squadron was formed at the outbreak of World War II and deployed to New Guinea, first flying ex-QANTAS "Empire" flying boats and later "Catalinas". In addition to long-range surveillance, the Squadron carried out bombing missions on Japanese-held islands east of New Guinea, including Guadalcanal. In 1942 the Squadron re-deployed to North Queensland and in 1944 to New South Wales. Three Squadron aircraft laid mines in Manila Harbor in December 1944.

After the war, No. 11 Squadron re-formed with Mk 30 "Lincolns" and re-equipped with P2V-5 "Neptunes" beginning 1951. Six years later the Squadron performed one of the RAAF's most ambitious peacetime exercises, Operation West Bound. During six weeks, three No. 11 Squadron P2V-5s flew 30,000 miles around the world, crossing the equator on four separate occasions. This was the first time a formation of RAAF aircraft had circled the world.

The Squadron continued operating its "Neptunes" until 1968, when it transitioned to P-3B "Orions". No. 11 Squadron trained with the USN's VP-31 at NAS Moffett Field to master the P-3B, then returned to Australia and moved from Richmond N.S.W. to its present location.

In 1970, HRH Prince Philip presented the Squadron with its own Standard for 25 years meritorious service. Last year No. 11 Squadron was co-winner with a Canadian Squadron of the coveted Fincastle Trophy for ASW proficiency.

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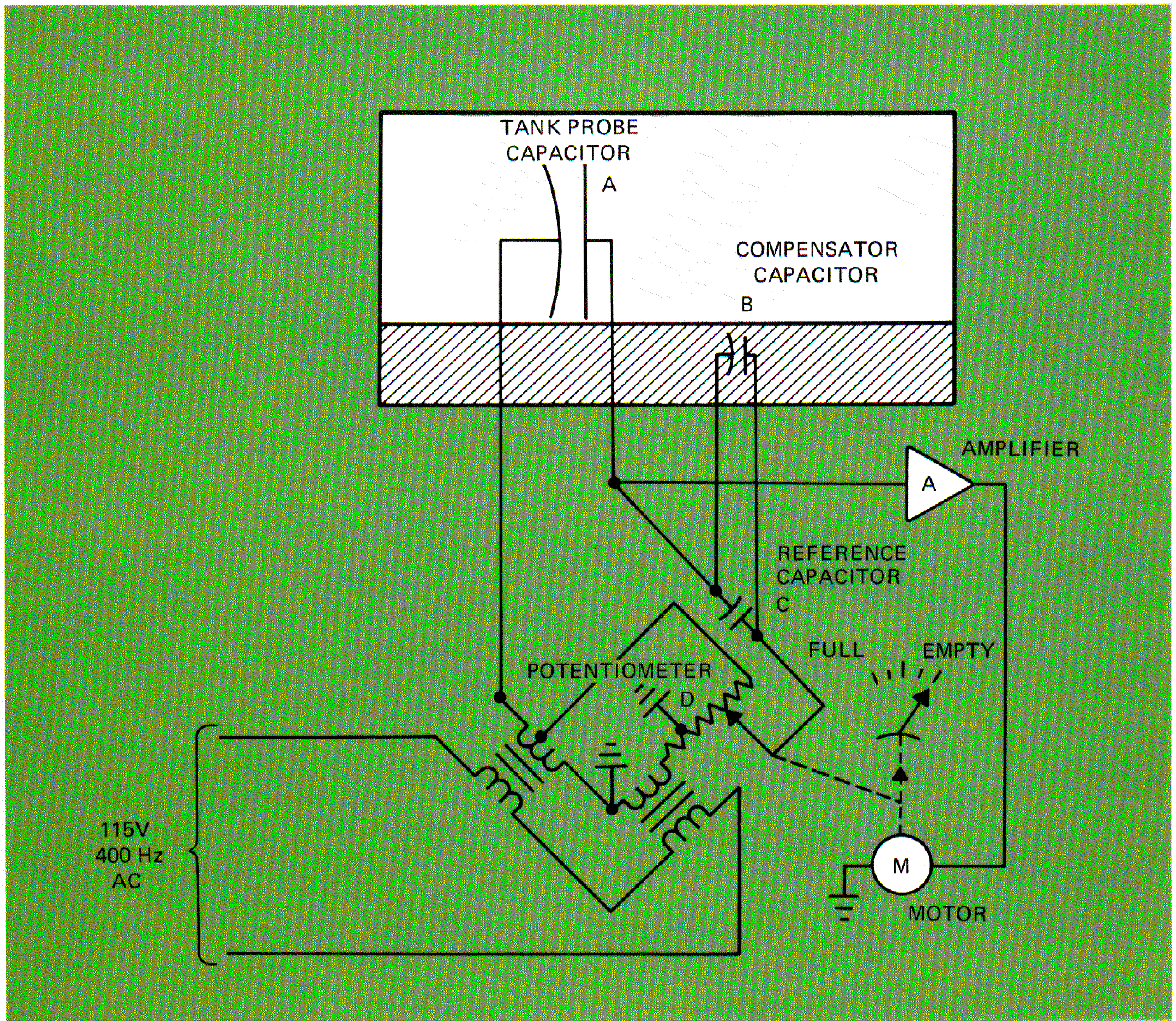
INTRODUCTION

The long-range P-3 Orion has special requirements for fuel quantity measurement and indication. The Orion's large, multiple fuel tanks of varying shapes, together with its ability to utilize fuels of widely differing densities, pose difficult challenges to the designer whose task is to devise a highly accurate and dependable fuel quantity measurement system. All long-range airplanes equipped with integral fuel tanks have posed similar problems. However, the P-3's mission regularly requires takeoffs at or near maximum gross weight for flights of indeterminate range and endurance, therefore such an indicating system is a *must*. These requirements are met by the capacitance-type "Simmonds Pacitron Fuel Quantity Gaging System" produced by Simmonds Precision Products, Inc. This type of system has been proved on numerous models of modern aircraft, including the first generation commercial and military jet transports and the wide-bodied transports of today.

Due to the vital function of the fuel quantity indicating system, it is imperative that the system be properly calibrated and maintained. Some consequences of an inaccurate system are obvious, while others are not as apparent. Indicators that read too high probably would lead the flight crew to be unwarrantedly optimistic about their fuel reserves. If this situation is compounded by circumstances that require an unplanned heavy increase in fuel consumption, the fuel supply could be exhausted and force the airplane down. On the other hand, indicators that read too low could cause too much fuel to be taken aboard the airplane. This may result in overweight takeoffs and landings, which in turn could lead to accelerated wear and strain on the airframe.

The purpose of this article is to provide information that will aid the interested reader to better understand the P-3 fuel quantity indicating system. It is especially directed to those who are concerned with maintenance procedures. We will present a general discussion on the theory of capacitance-type liquid measurement, describe the P-3 fuel quantity indicating system, present the latest maintenance information, and discuss the capabilities of manual fuel measurement cross-checks.

Figure 1. Simplified Schematic of Fuel Quantity Indicating System



VARIABLE CAPACITANCE MEASUREMENT

A broad background in electronics, particularly in the field of capacitive reactance, would be of great help in reaching a thorough understanding of how the P-3 fuel quantity indicating system functions. However, a good working-knowledge of the system can be gained by anyone having generalized experience in aviation instrumentation. For the benefit of the many personnel unavoidably concerned with this system who are not necessarily electronics experts, Figure 1 presents a greatly simplified schematic of capacitance-type measuring and indicating circuitry, and the following discussion is based upon this schematic.

SYSTEM THEORY AND FUNCTION The capacitance-type fuel quantity indicating system used on the Orion is basically a continuously rebalanced bridge circuit. Fuel quantity is measured electronically by devices immersed in fuel that function as capacitors, with fuel, air, or a combination of both serving as the material between the plates of the capacitance-type device. Signals from the measuring devices are translated by the indicator and displayed as total fuel weight in the tank.

If we assume that the capacitance of the measuring device (tank probe unit) is proportional to the density of the material between its plates, it is evident that both "A" and "B" capacitors shown in Figure 1 can function as *variable* capacitors. Since air has a lower density than fuel, the capacitance of "A" (the tank probe unit) will be least when the tank is nearly empty and "A" is filled with air, as illustrated in Figure 1. Conversely, the capacitance of "A" will be greatest when it is completely filled with fuel. Thus, "A" measures liquid *volume*.

Variation of fuel density is another factor that must be taken into account, for the greater the fuel density, the greater is the capacitance of the measuring device immersed in it. Since compensating capacitor "B" is always totally immersed when fuel is in the tank, it acts as a variable capacitor that senses changes of liquid *density* due either to changes of temperature or to differences of the specific gravities of various fuels. Figure 2 is a graph which shows the density variations of JP-4 and JP-5 fuels, variations for which compensation must be made.

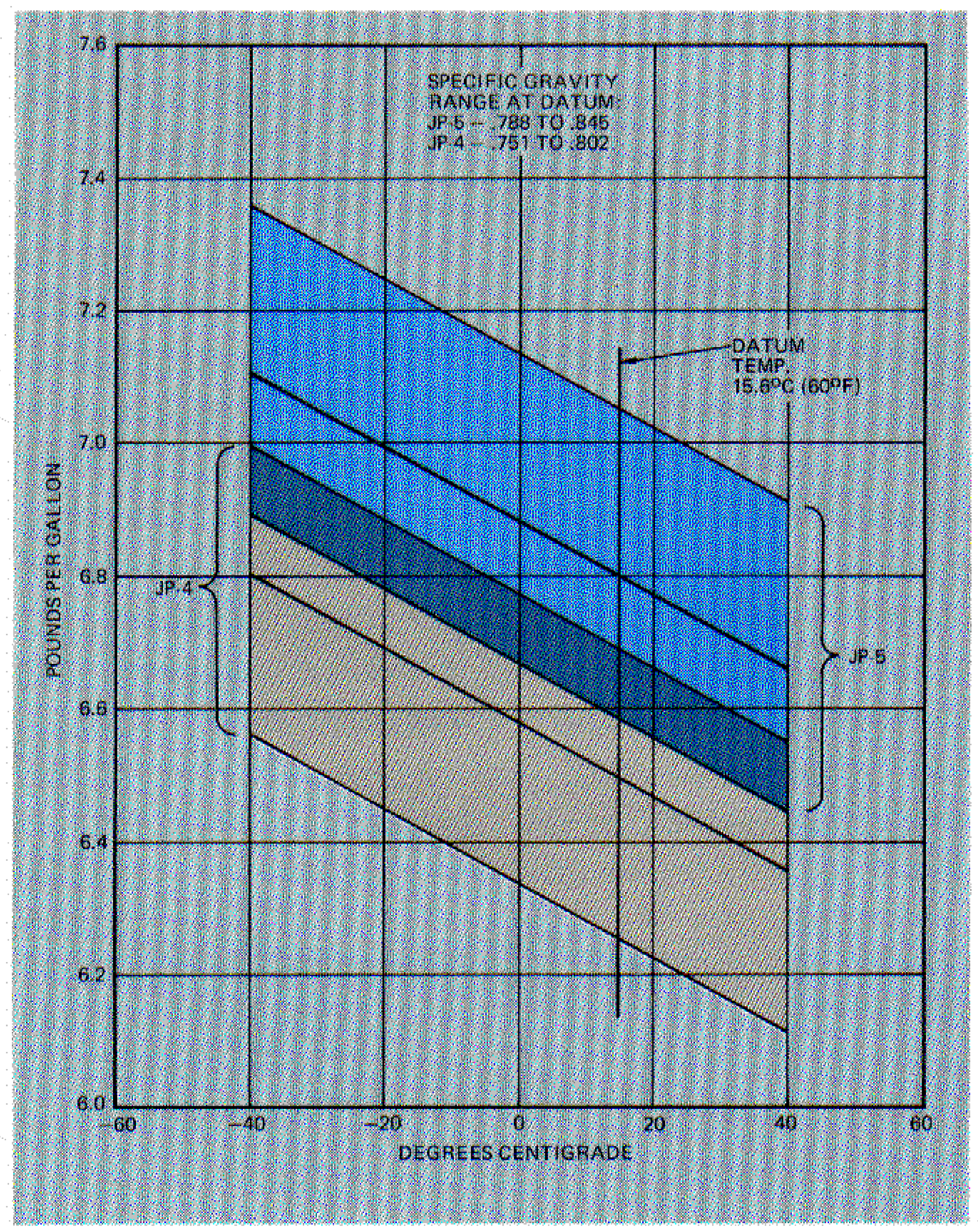


Figure 2. Fuel Density Envelopes of JP-4 and JP-5

As shown in Figure 1, the indicating system uses 115-volt, 400 Hz ac power. The indicator is a continuously rebalanced bridge circuit in which the capacitance of tank probe unit "A" is compared to the collective reference capacitance of compensator "B" and reference capacitor "C", which are connected in parallel and form the reference leg of the bridge circuit. As fuel is added or removed from the tank, a signal proportional to the difference between the capacitance of "A" and the collective capacitance of "B" and "C" is amplified to operate a motor. The motor repositions potentiometer "D" to restore the bridge circuit to balance and mechanically positions the indicator pointer. When the bridge circuit is restored to balance, the signal to the amplifier is nulled, and the motor is de-energized. The degree of correction required by potentiometer "D" is an indication of the capacitance of tank probe unit "A", and thus an indication of the quantity of fuel in the tank.

If the fuel level rises or falls in capacitor "A" because a temperature change has caused a change in fuel density, the variations of the fuel-air combination between the plates of "A" will cause the capacitance of "A" to change but the actual fuel weight in the tank will remain the same. Here the purpose of capacitor "B" becomes evident, for as fuel level variations due to changes in density change the capacitance of "A", these same density changes simultaneously change the capacitance of "B" which is totally immersed in fuel. These changes tend to cancel one another in the bridge circuit so that there is no significant change of fuel weight indicated due to fuel density variation. This compensating function is particularly important on the P-3 because of the great effect density variation has, in terms of total fuel weight, when more than 9,000 gallons of fuel are involved.

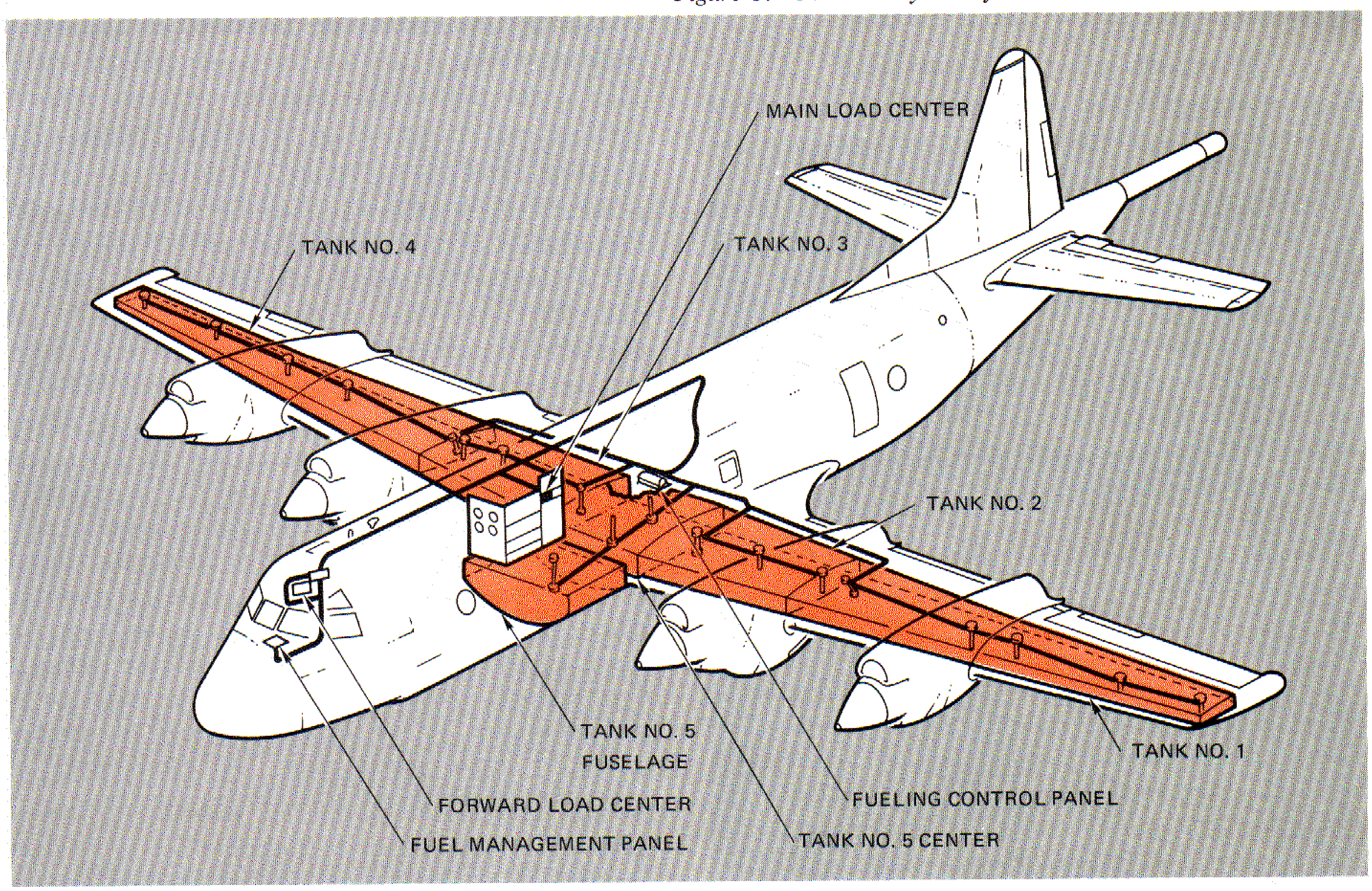
In summation, the fuel tank probes provide an electrical signal of the number of gallons, the compensator provides a signal of fuel-weight-per-gallon, and the indicator performs the multiplication and displays the product in terms of true fuel weight for the individual tank.

P-3 FUEL QUANTITY INDICATING SYSTEM

The P-3 fuel quantity indicating system consists of five sets of variable capacitance-type fuel level probes, one set in each of the aircraft's five fuel tanks; indicating instruments and test switches mounted on the Fuel Management Panel in the flight station, and on the Fueling Control Panel at the lower aft right fuselage-to-wing fillet; and the associated electrical circuitry of the system.

PROBES Each fuel tank is equipped with an individual set of variable capacitance-type fuel level measuring probes. The two outboard wing tanks have five-probe sets, while the two inboard wing tanks and the fuselage tank have three-probe sets. Figure 3 shows the general layout of the fuel tanks and the arrangement of the fuel probes within them. All wing tank probes are top-mounted, and the probes for opposite equal wing stations are interchangeable, *except for the inboard probes of the outboard tanks* which are canted in respect to their mounting flange and must be used only in the tank for which they were designed. The fuselage tank probes are bottom-mounted and are *not*

Figure 3. General Layout of P-3 Fuel Tanks and Probe Units



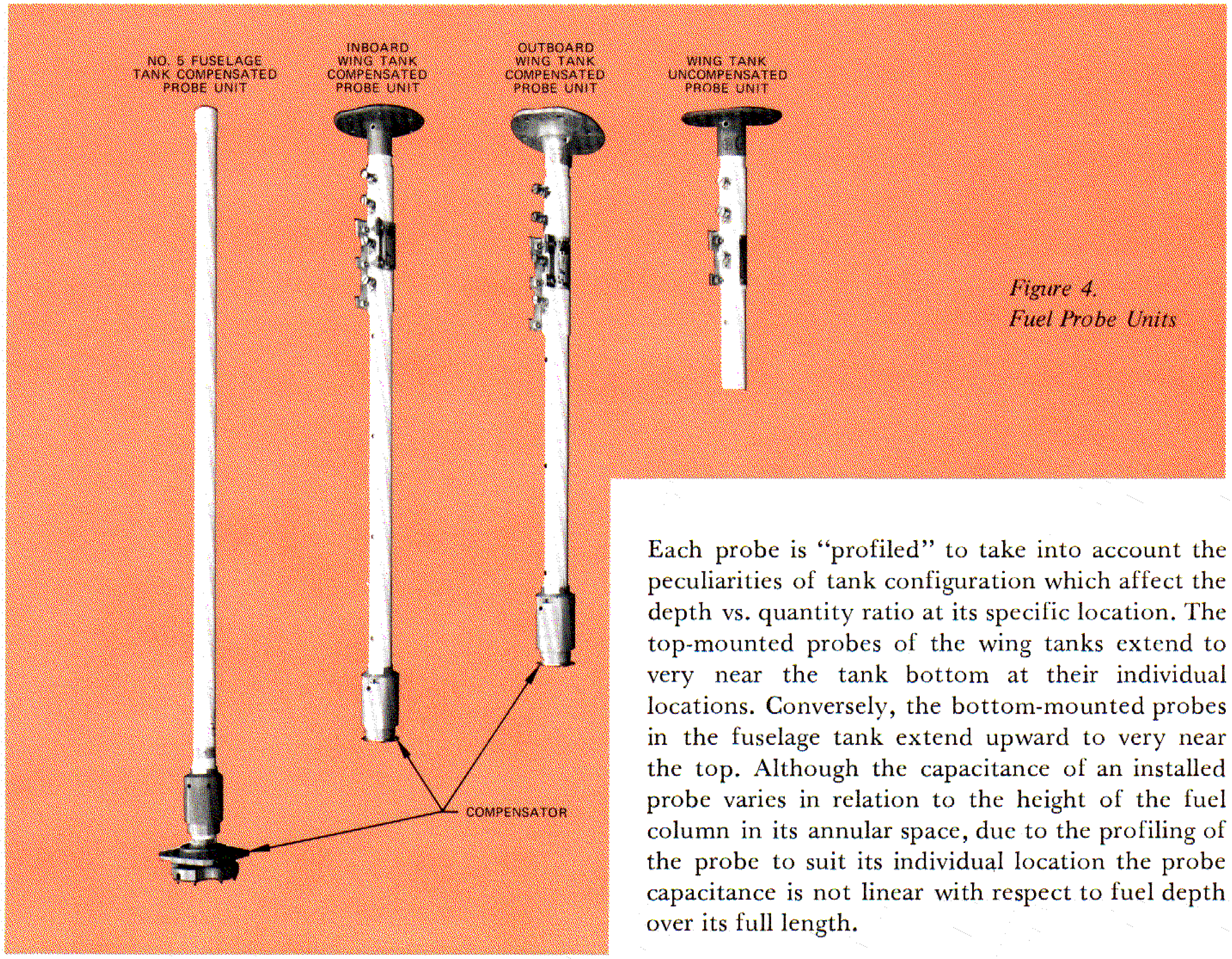


Figure 4.
Fuel Probe Units

interchangeable with either the wing tank probes or with one another. Examples of tank fuel probes are shown in Figure 4.

Each fuel probe is an elongated electrical capacitor which consists of two fiberglas tubes, one inside the other. The tubes are epoxy-bonded at one end to a metal mounting flange, are physically separated by a relatively wide annular space, and are open at the other end. Conductive coatings deposited on the inside surface of the larger tube and on the outside surface of the smaller tube act as the plates of the capacitor. The air, fuel, or a combination of both in the annular space serves as the dielectric element of the capacitor. Holes through the outer tubes allow free flooding of the annular space. A conductive coating on the inner surface of the smaller tube serves as a ground to remove stray capacitance from the system.

Each probe is "profiled" to take into account the peculiarities of tank configuration which affect the depth vs. quantity ratio at its specific location. The top-mounted probes of the wing tanks extend to very near the tank bottom at their individual locations. Conversely, the bottom-mounted probes in the fuselage tank extend upward to very near the top. Although the capacitance of an installed probe varies in relation to the height of the fuel column in its annular space, due to the profiling of the probe to suit its individual location the probe capacitance is not linear with respect to fuel depth over its full length.

The probe at the deepest point in each tank incorporates a compensator at its lower end, and the remainder of the probes in each tank are connected in parallel with the compensated probe—an arrangement which makes their capacitance signals directly additive. In effect, although there are multiple probes in each tank, they perform as a single probe, and in electrical terminology they are properly designated as "single probe installations." Figure 5 schematically illustrates the circuitry between the compensated probe and the uncompensated probes, which is typical of all tanks. Also shown is a schematic of the B952 Adapter Cable used during system calibration.

INDICATORS The "master" fuel quantity indicator for each of the five fuel tanks and a fuel quantity totalizer are installed on the Fuel Management Panel in the flight station. A "slave" or

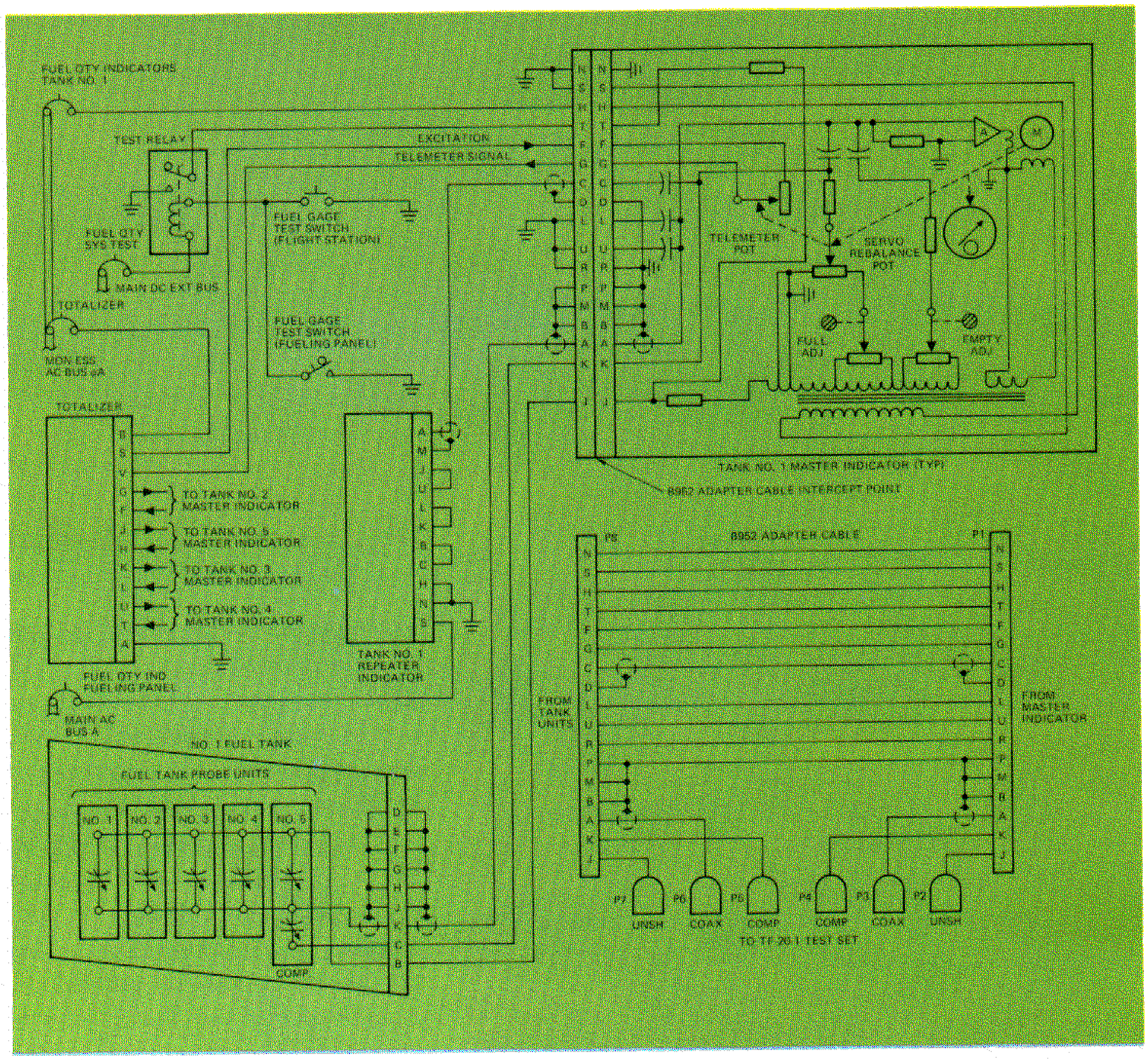
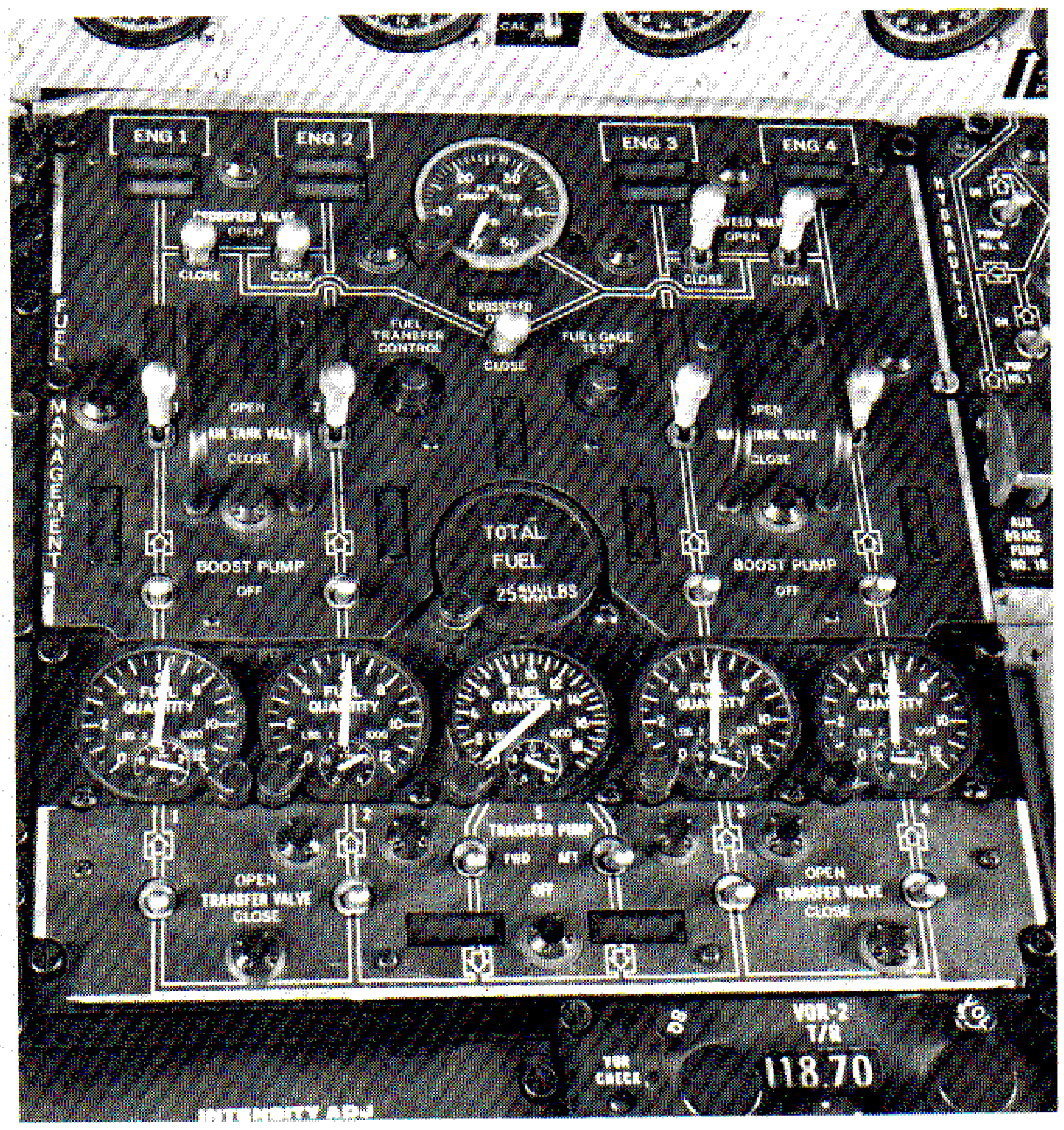


Figure 5. Schematic of Tank No. 1 Fuel Quantity Indicating System and B952 Adapter Cable Assembly

Figure 6. Fuel Management Panel



repeater indicator for each of the tanks is installed on the Fueling Control Panel. A fuel quantity indicator test switch is installed at both locations. The Fuel Management Panel and Fuel Control Panel are shown in Figures 6 and 7, respectively.

The tank indicators, 10 in all, are of identical design in two configurations—the 12,000 lb capacity indicators for the wing tanks (Figure 8), and the 19,000 lb capacity indicators for the fuselage tank (Figure 9). Each indicator is self-contained, enclosed in a hermetically-sealed case, and includes the dial, a transistorized amplifier-bridge circuit assembly, power supply circuitry (including "EMPTY" and "FULL" adjustment potentiometers), a two-phase indicator drive motor, a motor gear-box, and a rebalancing potentiometer. Any indicator may be interchanged with any other of identical capacity, provided that it is recalibrated to properly translate the signals available

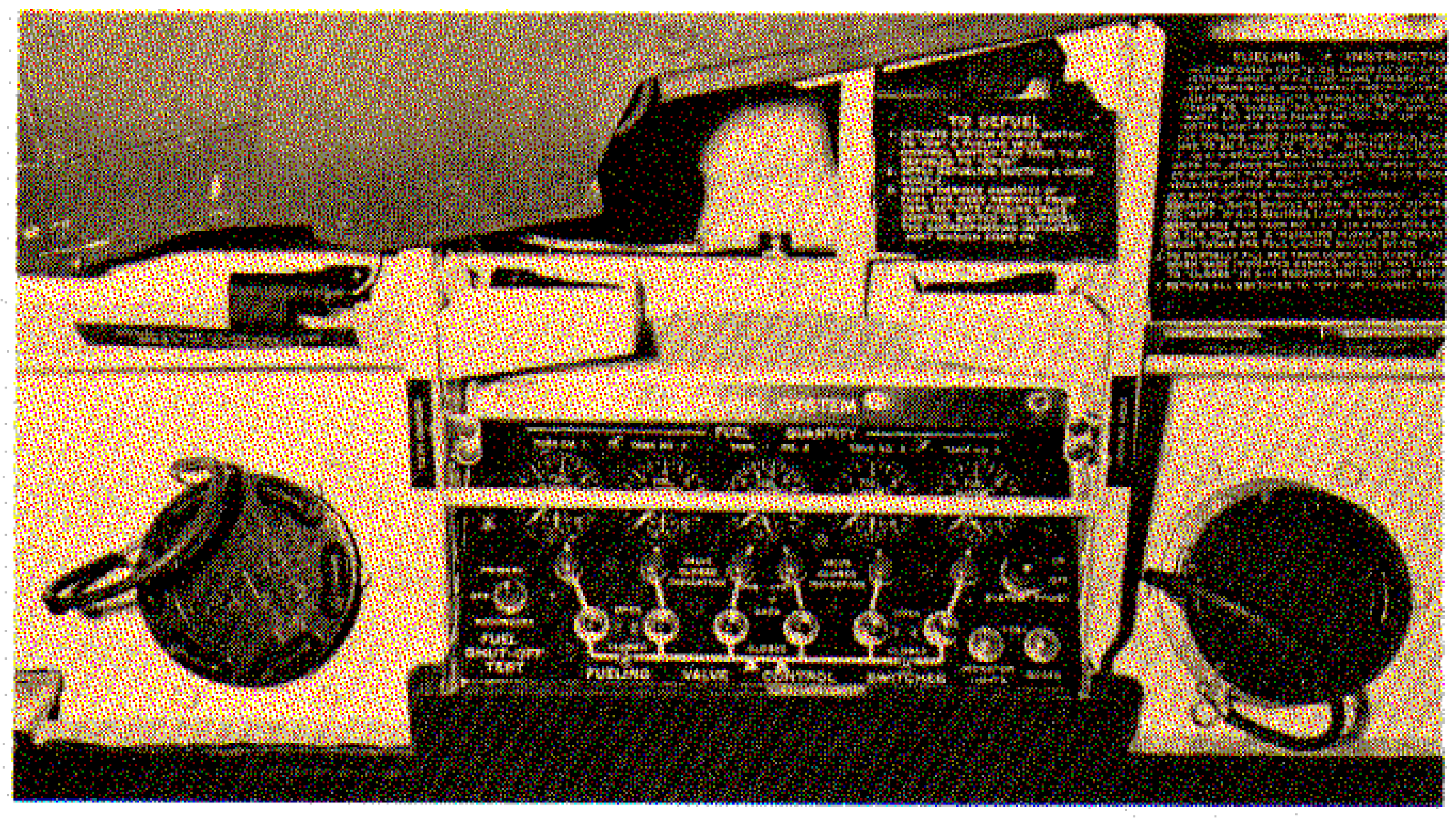


Figure 7. Fueling Control Panel

from the new location. Every indicator has the capability to perform either as a master (at the Fuel Management Panel) or as a repeater (at the Fueling Control Panel). Signals of capacitance from the related tank probe set (sensed signals) are utilized directly by the master indicator, which then produces a signal to operate the repeater.

The totalizer indicator, shown in Figure 10, is a digital-reading instrument capable of fuel quantity indications of up to 67,000 lb. This instrument sums the inputs from the five master indicators and displays the total quantity of fuel on board. The totalizer, also a hermetically-sealed unit approximately the same size as the tank indicators, includes power supply circuitry, summing circuits, an indicator drive motor, a motor gear-box, the digital indicating mechanism, and calibration controls.

ELECTRICAL SYSTEM The fuel quantity indicating system operates on 115-volt, 400-Hz, single phase ac power. All flight station fuel quantity indicators, including the totalizer, receive power from individual circuit breakers on Phase A of the Monitorable Essential AC Bus. The five Fueling Control Panel indicators are powered from a single circuit breaker on Phase A of Main AC Bus A. Power for the test circuit is supplied to K107 test relay from an individual circuit breaker on the 28-volt Extension Main DC Bus. All instruments, including the totalizer, contain a step-down transformer whose multiple secondary taps provide power for the instrument motor, sensing circuits, etc. The simplified schematic diagram of the No. 1 tank fuel quantity indicating system, shown in Figure 5, may be considered functionally typical of the indicating systems for the other four fuel tanks.

Although the master and repeater indicators utilize Phase A ac power from separate buses, the P-3's bus transfer system is such that these buses normally procure power from a common generating source so that voltage alternations coincide precisely. For this reason, the power and ground wiring of the connectors at the repeater indicator is the reverse of that at the master, ensuring that the instruments operate exactly 180° out-of-phase with one another. This is essential for proper

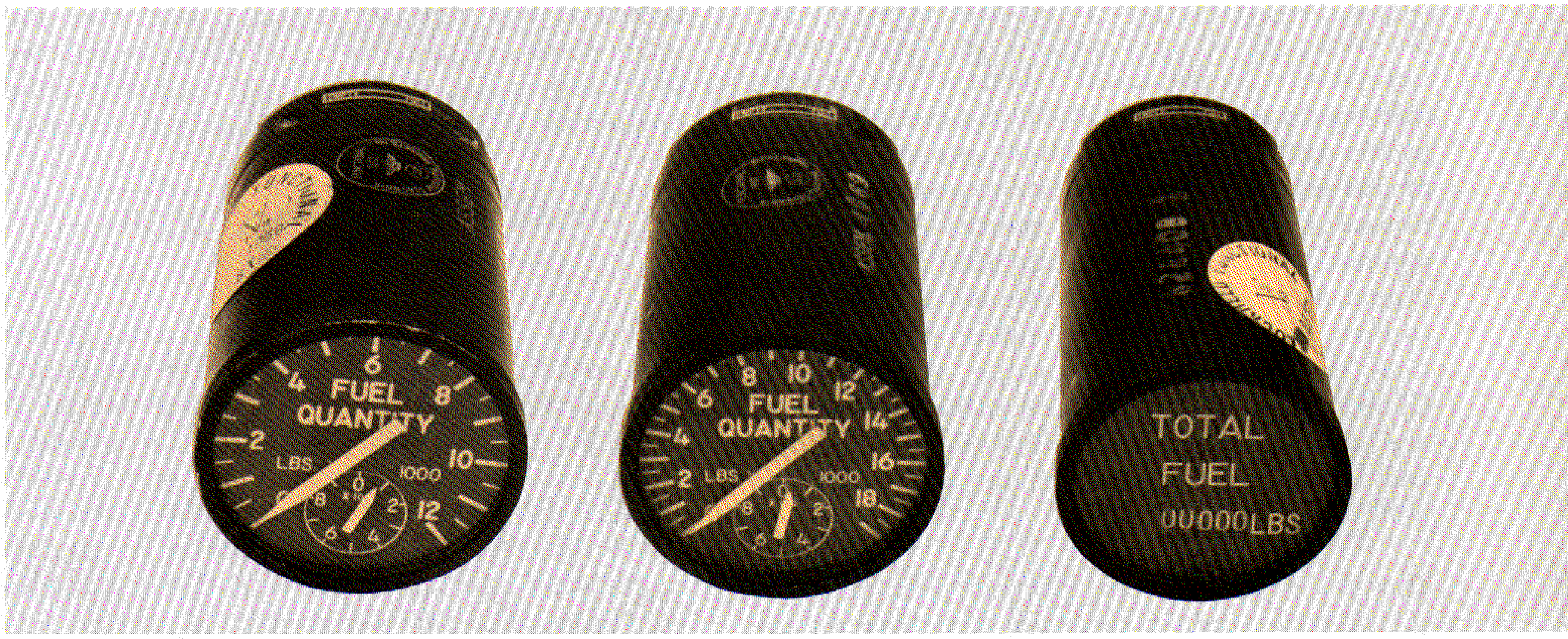


Figure 8. Fuel Quantity Indicator – Wing Tank

Figure 9. Fuel Quantity Indicator – Fuselage Tank

Figure 10. Totalizer Indicator

system operation, for it permits the repeater indicator to correctly translate the "reflected" signal from its master. If a bus-transfer malfunction should ever result in the masters and repeaters being connected to different alternators, the master-repeater phase relationship is destroyed and the repeater cannot reflect the reading of the master. In such an event, system design protects the master indicators, and their functional integrity will not be degraded.

SYSTEM OPERATION The P-3 fuel quantity indicating system principles of operation are basically the same as those presented in the "Variable Capacitance Measurement" section. The primary differences are: (a) instead of only one probe unit in the tank, there are multiple probe units connected in parallel that function as a single unit; (b) instead of one indicating system there are five systems, one per tank, each with its individual master indicator; (c) a repeater indicator is slaved to each master so that the quantity of fuel in each tank can be displayed remotely at the Fueling Control Panel; (d) a totalizer is included to sum and display the total quantity of fuel on board; and (e) a test circuit is included to demonstrate indicator operation.

The probe set, including the compensator, form the variable legs of the tank indicating system amplifier-bridge circuit. The remainder of the amplifier-bridge circuit is contained in the master indicator. When the probes sense a change in fuel quantity, the bridge circuit is unbalanced. The amplifier portion of the amplifier-bridge circuit amplifies the signal from the circuit to drive the indicator motor, which drives the instrument's pointer and repositions a rebalance potentiometer until the signal from the unbalanced leg of the circuit (the probes) is nulled.

The master indicator supplies outputs to two other components of the system. One output is tapped off the wiper arm of the rebalance potentiometer and fed to the repeater indicator. A second output is obtained from a telemetering potentiometer which is mechanically coupled to the rebalance potentiometer. This output, proportionate to indicated quantity, is sent to the summing circuit of the totalizer indicator. The totalizer sums the telemetering outputs of all five master indicators, and displays the total quantity of fuel on board.

SYSTEM TEST Indicator operation can be checked by actuation of the fuel quantity indicator test circuit. Push-to-test switches are installed on the Fuel Management Panel and the Fueling Control Panel. When either TEST switch is actuated, a test relay (K107) is energized, which completes a circuit to all master indicators and causes them to drive down-scale. Movement of the master indicators is signaled to the totalizer and the repeaters, causing these indicators also to drive down-scale. Any master indicator that does not move down-scale when the TEST switch is depressed is defective; any repeater indicator that does not move down-scale with its master during system test is defective; any totalizer that does not move down-scale with the master indicators is defective.

QUANTITY INDICATING ERRORS

In judging the performance of an indicating system on a specific aircraft, it is important to understand the tolerance for error allowed in installations of this type. The controlling document at the time of design, MIL-G-7940A, specified that on a properly installed and adjusted system, gage indication shall not deviate from actual fuel weight more than 4% of indicated plus 2% of full-scale. Thus, as shown in Figure 11, the permissible error can vary considerably according to the amount of fuel being measured and the total tank capacity.

The P-3's Pacitron system ordinarily yields readings well within this tolerance envelope if properly adjusted and maintained. The peak fidelity which a given tank system may attain through careful adjustment cannot be specified, as this will be an individual system trait – the result of the build-up of various tolerances in the probes, indicators, etc., of the system in question. It can be said, however, that the need for system maintenance is evident if accuracy is proven to be less than specified in MIL-G-7940A. As mentioned in a previous article (Orion Service Digest, Issue 19) covering fueling and defueling, the best method for determining the accuracy of a fuel quantity indicating system is defueling or fueling the tank in increments of known weight. It follows that the Figure 11 graph can serve as a trouble shooting guide if it is utilized intelligently for line-maintenance.

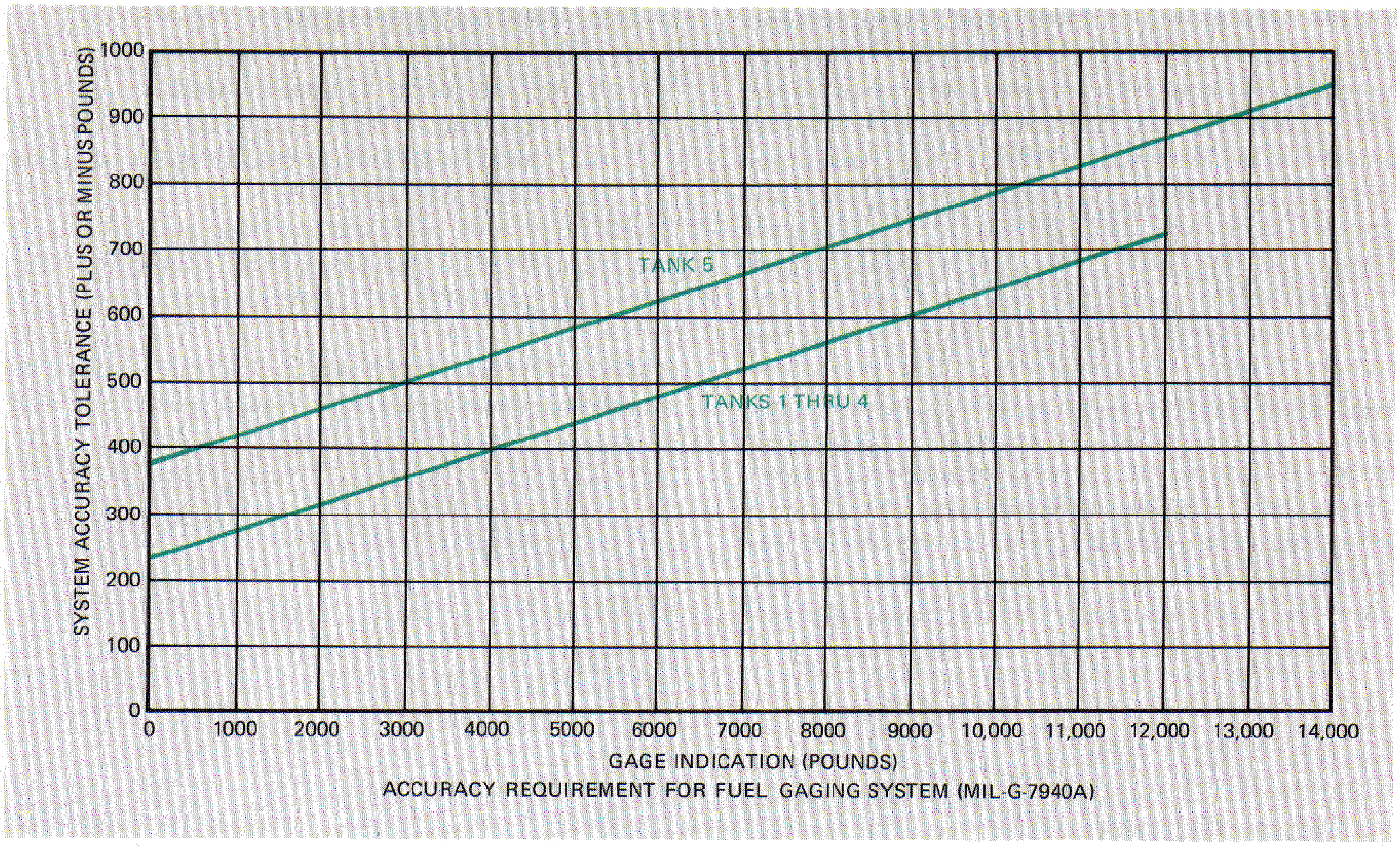


Figure 11. Capacitance-Type Liquid Quantity Gaging System Accuracy Requirements (MIL-G-7940A)

For example, if a tank is defueled to investigate indicator trouble, during defueling the indicator performance can be plotted and compared to the true weight of the fuel increments and total fuel removed. Careful evaluation of such a plot may verify or disprove the need to maintenance and serve as a valuable troubleshooting aid. Thereafter, if a similar plot is made while fueling, comparison with the defueling plot will prove the effectivity of repairs and adjustments.

The narrow tolerance for error at lower levels defined in MIL-G-7940A establishes what may be termed a basic "design philosophy" which is inherent in the P-3's capacitance probe systems. These systems reflect the product of two factors (a probe signal of sensed gallons and a compensator signal of sensed weight-per-gallon) and consequently tend to be increasingly accurate at lower levels and vise versa. It is important to bear in mind this inherent "nature" of the system when troubleshooting signal errors. A seriously faulty compensator signal of density can produce a vast error when hundreds of gallons are involved at high tank levels, but the increment of error will diminish at lower levels. In fact, a properly calibrated system instrument will register zero when the tank is empty regardless of compensator error, for at zero gallons the reported weight per gallon is of no further significance. On the other hand, an erroneous probe signal of gallonage tends to produce a uniform increment of error at all tank levels to (and including) empty.

SYSTEM CALIBRATION AND ADJUSTMENT

The fuel quantity indicating system must be recalibrated whenever an erroneous indication is experienced or suspected, or whenever any system component has been adjusted, repaired, replaced, or exchanged. All or part of the fuel quantity indicating system can be calibrated with the fuel tanks either wet or dry, but greater system accuracy can be realized with the dry-tank procedure because calibration can be based on system capacitance measurements made concurrently with system calibration. Calibration of the system while the fuel tanks are wet has the potential for lower accuracy because the logged or "nominal" capacitance values used during the procedure may no longer be accurate.

System calibration and adjustment requirements depend upon which components have been adjusted or replaced. A complete calibration of the entire fuel quantity indicating system requires simulation of the capacitance of each tank probe unit set, adjustment of each pair of master and repeater indicators, and adjustment of the system totalizer. If only part of the system requires repair or adjustment, only the indicator set of the affected sub-system and the totalizer require calibration. Figure 12 shows which test procedures must be performed after a specific system component or combination of components have been replaced. *Note that the recorded capacitance values of a fuel tank sub-system are no longer valid once a probe unit or system wiring has been replaced. The capacitance of the sub-system must be remeasured, otherwise the inherently less accurate nominal acceptable capacitance values must be used.*

Recently a team from Lockheed-California Company verified a revised set of maintenance procedures for measuring the capacitance of the P-3 fuel quantity indicating system, and for calibrating the system indicators when the fuel tanks are either wet or dry. These procedures were verified on a P-3 aircraft at NAS Moffett Field with the assistance and cooperation of VP-9, VP-48 and COMFAIRWINGSPAC. These revised procedures are included in this article, and will be published in the near future as a revision to NAVAIR 01-75PAA-2-4 which is the official source of maintenance information pertaining to the P-3 fuel quantity indicating system.

COMPONENT REPLACED	ACTION				CONDITION	
	CHECK TANK UNITS	CALIBRATE MASTER INDICATOR	CALIBRATE REPEATER INDICATOR	CALIBRATE TOTALIZER	FUEL TANK(S) DRY	PERFORM WET TANK CROSS-CHECK
TANK UNIT(S)	X	X	X	X	X	X
MASTER INDICATOR		X	X	X		X
REPEATER INDICATOR		X	X	X		
TOTALIZER				X		

Figure 12. Calibration Requirements for Fuel Quantity Indicating System after Component Replacement

TEST EQUIPMENT The following test equipment is required for fuel quantity indicating system calibration and adjustment:

1. TF-20-1 Capacitance-type Liquid Quantity System Test Set
2. B952 Adapter Cable
3. B515 Safety Grounding Cable
4. F12076-603 Power Cable (part of B144 Cable Assembly Kit)
5. F12076-300 Totalizer Calibrator Kit (part of B144 Cable Assembly Kit)

The TF-20-1 test set shown in Figure 13 is used to simulate system capacitance during calibration and

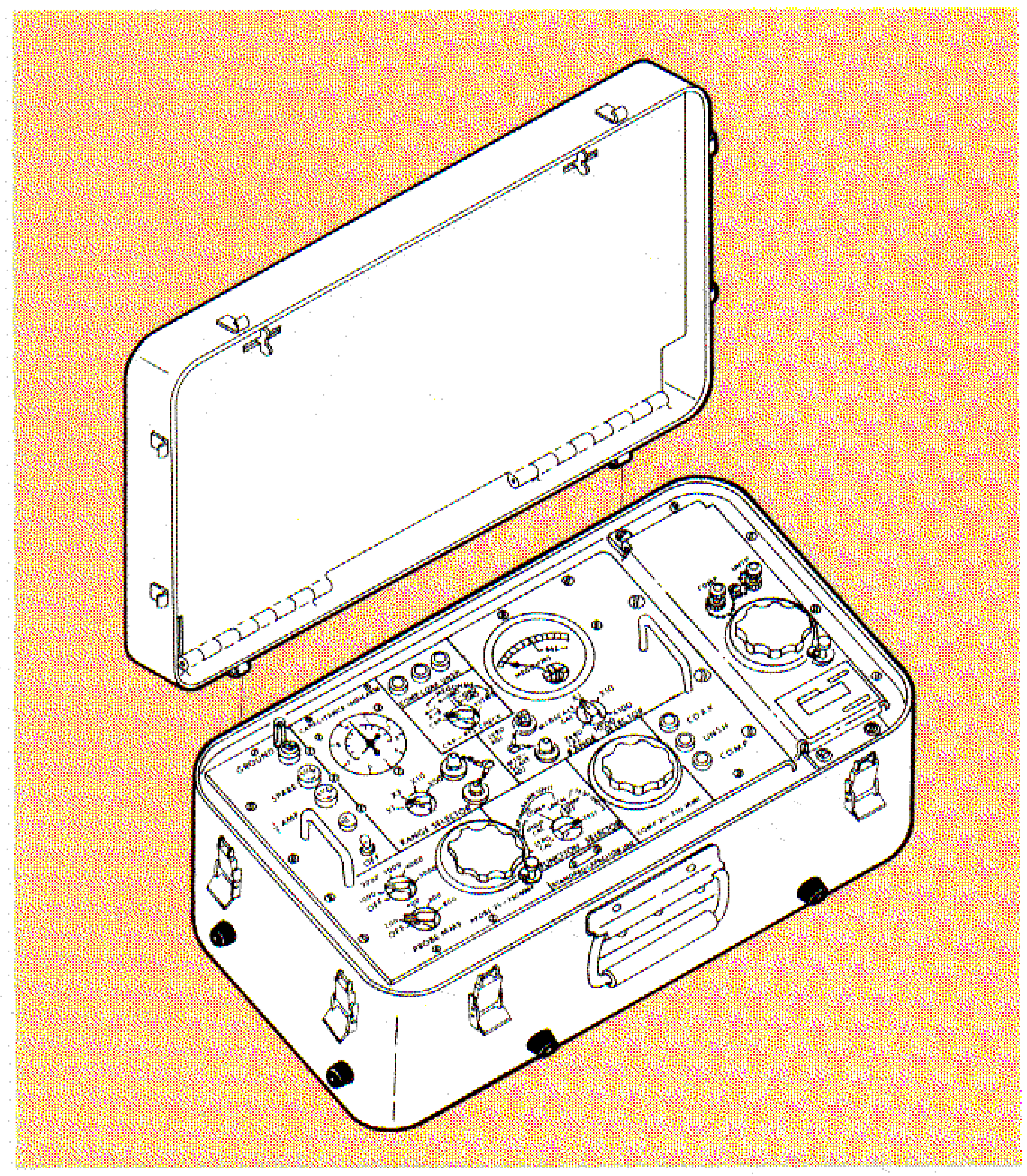


Figure 13. TF-20-1 Capacitance-Type Liquid Quantity System Test Set

adjustment of the master and repeater fuel tank indicators, and to measure the capacitance and insulation leakage resistance of the tank probe unit sets, the compensator units, and the system wiring between the tank and the master indicator. The TF-20-1 test set is connected in series with the aircraft wiring, using the B952 Adapter Cable (Figure 14) to intercept the wiring between the tank probe units and the master indicator in the flight station at the Fuel Management Panel. Figure 5 schematically shows the interface between the B952 Cable Assembly, the master indicator, and the system wiring. The B515 Safety Grounding Cable is used to ground the test set to the aircraft structure (pilots seat track) and to the master indicator aircraft harness plug of the tank system under calibration. The test set is supplied 115-volt, 400 Hz ac power from the aircraft through the F12076-603 Power Cable, which is part of the B144 Cable Assembly Kit.

Figure 15 is used to simulate signals from all five sets of tank probe units during calibration of the totalizer indicator. The totalizer calibrator intercepts the wiring from all five tank systems at the master indicators in the flight station, using cables that are integral with the F12076-300 unit. Simulated fuel quantity signals from the totalizer calibrator drive the master indicators through their complete range of operation, which in turn transmit these signals to the totalizer indicator. These inputs from the master indicators enable the technician to calibrate the totalizer from zero to full (67,000 lb). The F12076-300 totalizer calibrator is included as part of the B144 Cable Assembly Kit.

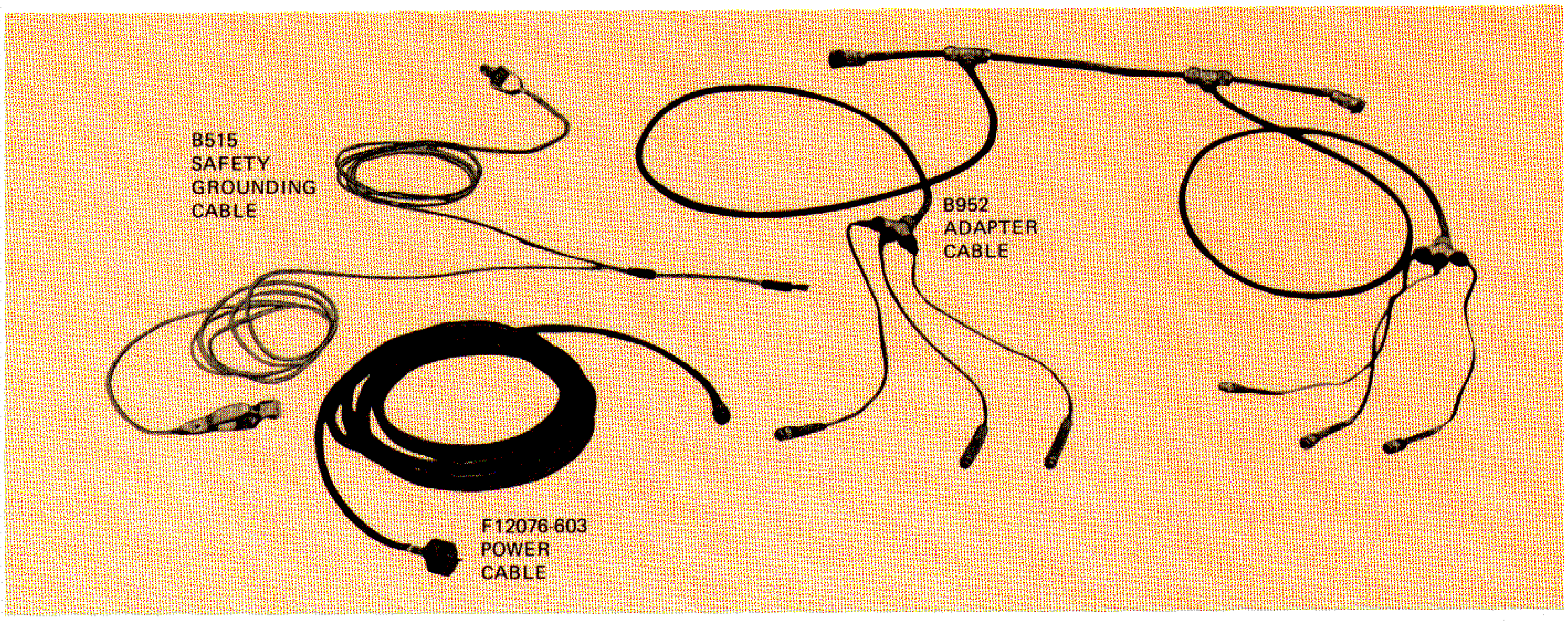


Figure 14. TF-20-1 Test Set Adapter, Power, and Grounding Cables

During each test procedure with the TF-20-1 test set, the capacitance of one set of tank components can be measured and/or one set of master and repeater indicators can be calibrated. If these procedures must be performed on the indicating systems of all five tanks, then the procedure must be repeated five times. The fuel totalizer indicator can *not* be calibrated or adjusted with the TF-20-1 test set.

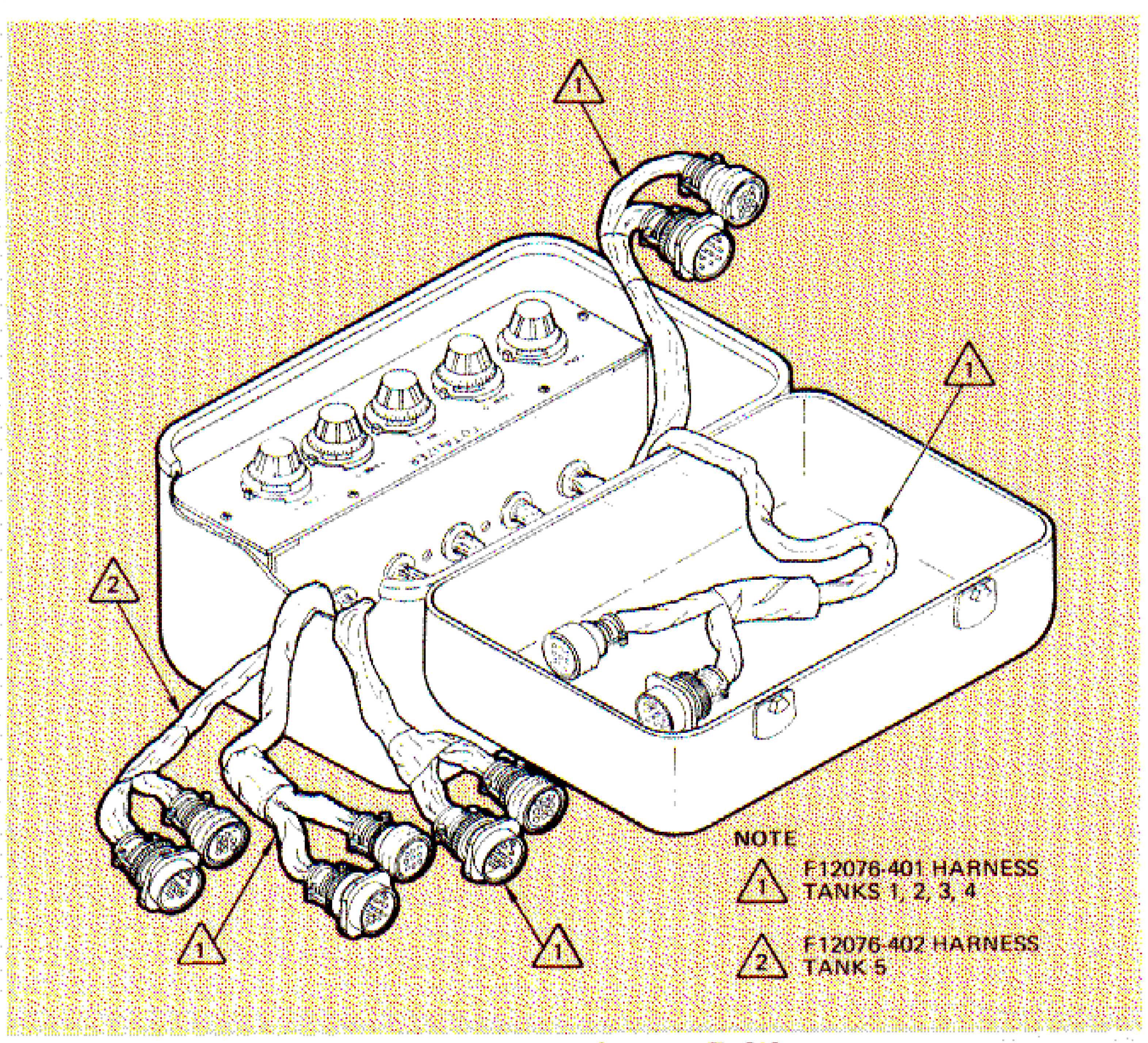


Figure 15. F12076-300 Totalizer Calibrator

The F-12076-300 totalizer calibrator shown in

It is imperative that the test equipment and cables be in good condition. Care must be exercised while setting up the test equipment to ensure that the adapter and ground cable connections are made properly. During performance of the calibration procedure, strict compliance with the test equipment operating instructions is mandatory, otherwise satisfactory calibration of the system gages can not be achieved.

CALIBRATION PROCEDURES Two men are required to perform the calibration procedure on the fuel quantity indicating system, one in the flight station to operate the test equipment and calibrate the master indicators and the other outside the aircraft to calibrate the repeater indicators. Communications between the personnel is afforded by the aircraft intercommunication system.

All P-3A and P-3B aircraft, and P-3C aircraft Serial No. 153443 through 158564 have a plate secured to the booster shift control cover in the flight station that provides nominal capacitance values for calibration of the fuel quantity indicating system. Lockheed Engineering has concluded, after conducting a thorough investigation of the current fuel quantity indicating system calibration procedures, that the capacitance values on this plate may not be representative of the systems in many P-3 aircraft. As a consequence, all P-3C aircraft Serial No. 158565 and subsequent will have a decal mounted on the booster shift control cover on which is entered system capacitance values measured on that particular aircraft prior to delivery. On all P-3 aircraft prior to Serial No. 158565, it is recommended that the capacitance of the aircraft's fuel tank probe unit sets and their compensators be measured and recorded in the aircraft log book the next time a "dry tank" check is performed. In the interim, the nominal values shown in Figure 16 are sufficiently accurate to perform a "wet tank" calibration of the fuel quantity indicating system. Capacitance measurements that are not within the limits shown in Figure 17 are cause to suspect defects in the system wiring or in the tank probe units.

Remember, whenever a probe unit is replaced or any system wiring between the Fuel Management Panel and the tank probe units is replaced, the logged or placarded values for that particular aircraft are no longer valid. Either the capacitance of the affected subsystem must be remeasured or the values shown in Figure 16 must be used for system calibration. Greater accuracy can be achieved if the system capacitances are remeasured.

Measuring System Capacitance and Dry Tank Calibration

The following procedure is used to (a) set up the TF-20-1 test set, (b) measure the capacitance of the probe unit set and compensator in one dry fuel tank, and (c) calibrate the indicating system master and repeater indicators of one dry fuel tank. If the capacitances of the entire aircraft fuel quantity indicating system are to be measured and the indicators for all five tanks are to be calibrated, this procedure must be repeated five times – once for each tank.

During the procedure all fuel is removed from the tank of the system whose indicators are to be calibrated. Be certain that the tank is *completely dry* before proceeding further with the procedure, otherwise the compensator capacitance measurement will be affected and render subsequent indicator calibration invalid. The parenthetical numbers used throughout the following procedures refer to the switches, connections, dials, etc. of the TF-20-1 test set and are called out on Figure 18.

FUEL SYSTEM CAPACITANCE VALUES IN MMF		TANKS 1	2	3	4	5
	TANKS					
LOGGED VALUE (APPROXIMATE)	EMPTY	167.3	174.0	174.0	166.3	221.2
CONSTANT	ADDED	201.4	201.4	201.4	201.4	258.4
RESULTANT	FULL	368.7	375.4	375.4	367.7	479.6
	COMPEN					
LOGGED VALUE (APPROXIMATE)	EMPTY	26.8	26.8	26.8	26.6	26.1
CONSTANT	ADDED	26.9	26.9	26.9	26.9	26.9
RESULTANT	FULL	53.7	53.7	53.7	53.5	53.0

NOTE: VALUES SHOWN IN THIS FIGURE ARE APPROXIMATE VALUES AVERAGED FROM MEASUREMENTS ON ONE AIRCRAFT. USE ACTUAL VALUES RECORDED IN AIRCRAFT LOG BOOK WHENEVER POSSIBLE.

Figure 16. Average of Fuel Quantity Indicating System Capacitance Values Measured on Several P-3 Aircraft

TANKS 1 AND 4	165.5 TO 169.5 MMF
TANKS 2 AND 3	172.8 TO 175.8 MMF
TANK 5	219.8 TO 223.8 MMF
COMPENSATOR	25.0 TO 27.5 MMF

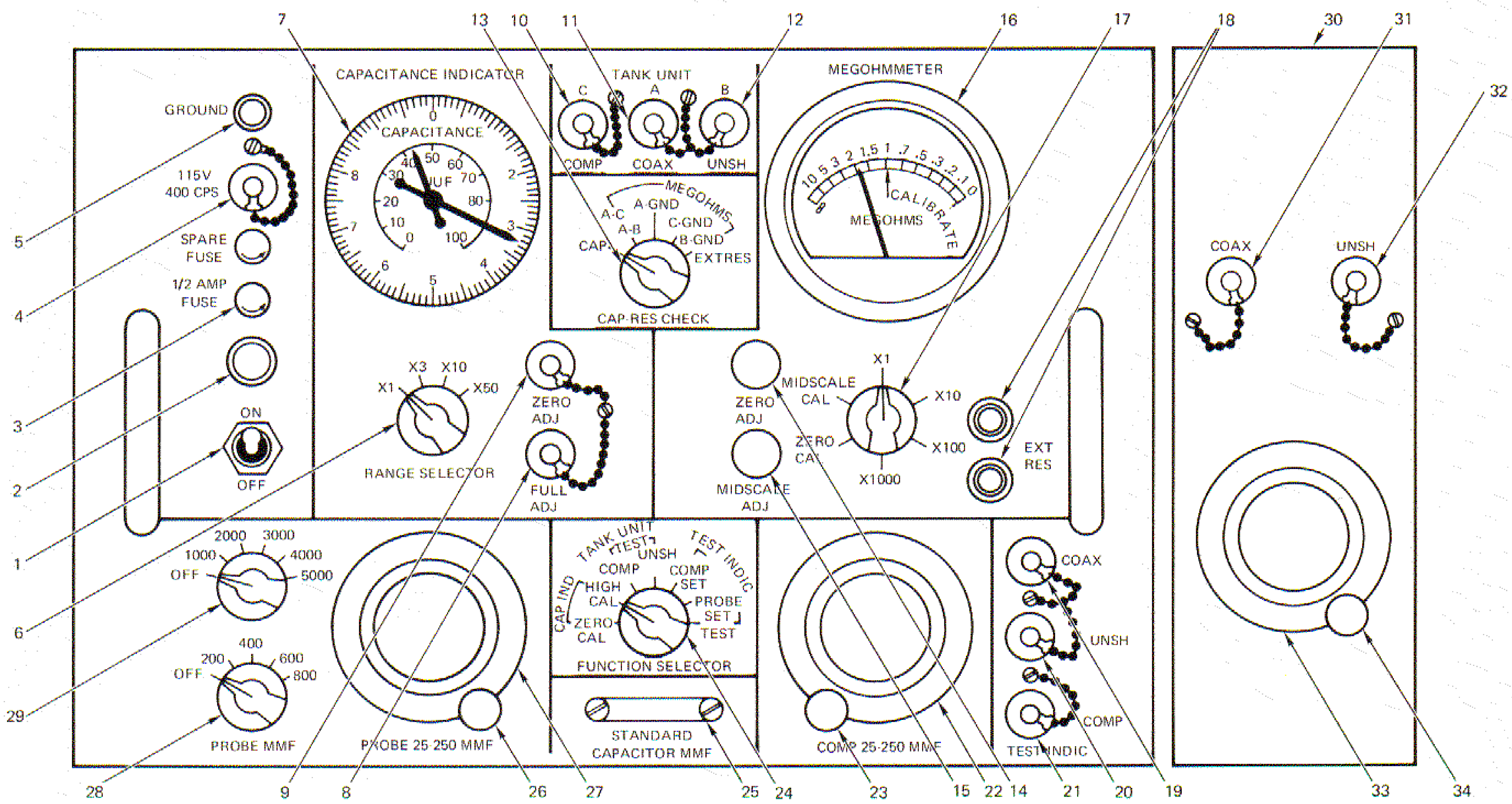
CAPACITANCE, AS MEASURED WITH THE TF-20-1 TEST SET, IN EXCESS OF THESE LIMITS IS CAUSE TO SUSPECT AIRCRAFT WIRING OR PROBE UNIT DEFECTS.

Figure 17. Fuel Quantity Indicating System Capacitance Measurement Limits

WARNING

The aircraft MUST be grounded to earth during calibration or capacitance measurement of the fuel quantity indicating system to minimize a hazard from sparks in the aircraft fuel tanks.

1. Connect an external source of 115-volt, 400 Hz ac power to the aircraft.



CAUTION OPERATE ONLY ON 115 VOLTS, 400 CPS. USE A 1/2 AMPERE 3 AG SLOW-BLOW FUSE ONLY

NOTE

THESE INSTRUCTIONS ARE FOR P-3A/B/C AIRCRAFT ONLY. SEE PLACARD IN TF-20-1 TEST SET FOR EXPLANATION OF INDEX NUMBERS.

CAPACITANCE METER (7): HOW TO READ.

For dial indication shown (7), and Capacitance RANGE SELECTOR in X1 position, a reading of 43.25 MMF is obtained. The last decimal place is estimated by eye. In the X3 position, this reading represents 43.25 x 3 = 129.75 MMF. Similarly, for the X10 and X50 positions, values are 432.5 MMF and 2162.5 MMF respectively.

RESISTANCE METER (16): HOW TO READ.

For indication shown (16), a reading of 1.8 megohms is indicated for the X1 Scale. On the X10, X100, and X1000 positions the values of 18, 180 and 1800 megohms are indicated respectively.

CALIBRATION OF TESTER FOR USE:

1. This tester has built-in standards for both resistance and capacitance indicator calibration. Front panel calibration controls are provided for each instrument. It is recommended that a periodic check be made against an independent Laboratory Standard.

2. Megohmmeter Calibration:
   (a) Set Megohmmeter Range Selector (17) to ZERO CAL position. Megohmmeter should indicate at zero calibration mark of MEGOHMMETER (16) dial. If it does not read properly, remove cover from ZERO ADJ control and adjust for proper reading.
   (b) Set Megohmmeter Range Selector (17) to MIDSCALE CAL position. Megohmmeter (16) should read 1. (If it does not, then remove cover of MIDSCALE ADJ (15) and set for proper reading).
   (c) Repeat both steps until no further adjustment is required. Replace both caps.

3. Capacitance Calibration:
   (a) Set Function Selector (24) to CAP IND-ZERO CAL position and Range Selector (6) to the X1 position. Capacitance indicator (7) should now read zero. If it does not, remove the protective cover of the ZERO ADJ (9) and correct indicator to read zero.
   (b) Set RANGE SELECTOR (6) to lowest range that will permit reading of the STANDARD CAPACITANCE value shown (25).
   (c) Set FUNCTION SELECTOR (24) to CAP IND-HIGH CAL position. The Capacitance Indicator (7) should read the value of the STANDARD CAPACITANCE (25). If the reading is incorrect remove the protective cover from the FULL ADJ (8) control and adjust to give proper indication.
   (d) Repeat procedure until no further adjustment is necessary.

Figure 18. TF-20-1 Test Set Panel and Calibration Instructions

2. Place EXTERNAL POWER switch on flight station right inboard overhead panel ON.

3. Close the following circuit breakers:

   a. FUEL QUANTITY INDICATORS-MONITORABLE ESSENTIAL AC BUS (Forward Load Center).

   b. FUEL QTY SYS TEST-EXTENSION MAIN DC BUS (Forward Load Center).

   c. FUEL QTY IND FUELING PNL-MAIN AC BUS A (Main Load Center).

4. Defuel the tank in accordance with the defueling procedures in NAVAIR 01-75PAA-2-4. Defueling must be performed with the aircraft positioned on its landing gear at a one-degree nose-down attitude and laterally level (see leveling procedures in NAVAIR 01-75PAA-2-1). This particular aircraft attitude must be maintained during defueling and refueling if indicator calibration is to be cross-checked with manual measurements. Each wing tank has a surge box at the lowest point in the tank. Drain the residual fuel from the surge box through the tank's water drain valve. Accuracy of dry tank indicator

calibration is contingent upon defueling the tank *completely*, and once emptied it must remain dry through the calibration procedure.

5. Connect F12076-603 Power Cable to TF-20-1 test set receptacle (4) and to 115-volt, 400 Hz ac aircraft utility outlet on Rack A in the flight station.

6. Place test set power switch (1) to ON position.

7. Check that power light (2) is illuminated.

NOTE

Allow test set to warm up for a minimum of five minutes before using set.

8. Check B952 Adapter Cable for physical damage, broken or bent connectors, or cracked insulation. Correct any faults with the cable before proceeding with the next step.

9. Connect B952 Adapter Cable to test set as follows:

    a. Connect adapter cable TANK UNIT lead P5/COMP to (10) on test set, P6/COAX to (11), and P7/UNSH to (12).

    b. Connect adapter cable TEST IND lead P2/UNSH to (20) on test set, P3/COAX to (19), and P4/COMP to (21).

10. Establish ICS communications between personnel at flight station and aircraft Fueling Panel.

11. Determine if master and repeater indicators of system to be calibrated read zero. If indicators do not read zero, remove the master indicator from the Fuel Management Panel (but do not uncouple indicator from connector) and rotate the EMPTY adjustment screw at the rear of the indicator until zero is indicated. *The EMPTY and FULL potentiometers have multi-turn adjustment screws (see Figure 19), consequently a considerable amount of adjustment may be necessary before the pointer begins to move.* After the master indicator is adjusted to zero, remove the repeater indicator from the Fueling Panel (but do not uncouple the indicator from the connector) and perform the EMPTY adjustment on it.

12. Open and tag FUEL QUANTITY INDICATOR circuit breaker of tank under test.

13. Remove master indicator of tank under test from the Fuel Management Panel, and uncouple the connector from the indicator. Connect the B952 Adapter Cable plug P1 to the indicator, and plug P8 to the aircraft wiring harness.

14. Connect B515 Safety Grounding Cable to the fuel quantity indicating system wiring by connecting one spring clip to the harness plug of the indicator under test, the spade lug to (5) on the test set, and the other spring clip to the pilots seat track.

15. Remove tag and close circuit breaker opened in step 12.

16. Calibrate TF-20-1 test set in accordance with instructions shown in Figure 18. These instructions have been extracted from NAVAIR 01-75PAA-2-4 Maintenance Instruction Manual. Disregard instructions on the general instruction placard furnished with the TF-20-1 test set except those coinciding with the instructions shown in Figure 18.

If system capacitance is to be measured, proceed with step 17. If logged capacitance values are to be used, proceed with step 29.

The capacitance values obtained in the following procedure should be recorded in the log book of P-3 aircraft Serial No. 158564 and earlier, or recorded on the decal on the booster shift control cover of P-3 aircraft Serial No. 158565 and subsequent. *These values take precedence over any values previously measured for the tank under test on that particular aircraft.* See Figure 17 for capacitance measurement limits.

17. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-COMP, place RANGE SELECTOR switch (6) to X1 position, and read compensator value on CAPACITANCE INDICATOR (7).

18. Log value obtained in step 17 in COMPEN EMPTY column of tank under test (see Figure 16).

19. Add 26.9 MMF to COMPEN EMPTY value logged in step 18 and log resultant value in COMPEN FULL column of tank under test.

20. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-UNSH. Place RANGE SELECTOR switch (6) to X3 position, read tank probe unit set capacitance on CAPACITANCE INDICATOR (7), and multiply this value by 3.

21. Record the value measured in step 20.

22. Place RANGE SELECTOR switch (6) to X3 position, and FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position.

23. Loosen clamp (26), rotate PROBE 25-250 MMF simulator (27) until the capacitance value recorded in step 21 is indicated on CAPACITANCE INDICATOR (7), then tighten clamp (26).

24. Set FUNCTION SELECTOR switch (24) to TEST INDIC-TEST position. The master and repeater indicators shall read zero. If indicators read zero, log value recorded in step 21 in TANKS EMPTY column of tank under test and proceed with step 28. If indicators do not read zero, do not log value recorded in step 21 and proceed with step 25.

25. If zero is not obtained in step 24, loosen clamp (26) and rotate PROBE 25-250 MMF simulator (27) until the master indicator reads zero.

26. Place FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position and read the capacitance on CAPACITANCE INDICATOR (7).

27. Log value obtained in step 26 in TANKS EMPTY column of tank under test.

28. Add value logged in step 24 or step 27 to 201.4 MMF (for tanks 1 through 4) or 258.4 MMF (for tank 5 only), and place the resultant value in the TANKS FULL column of the tank under test.

Steps 29 through 36 are used to check the system capacitance.

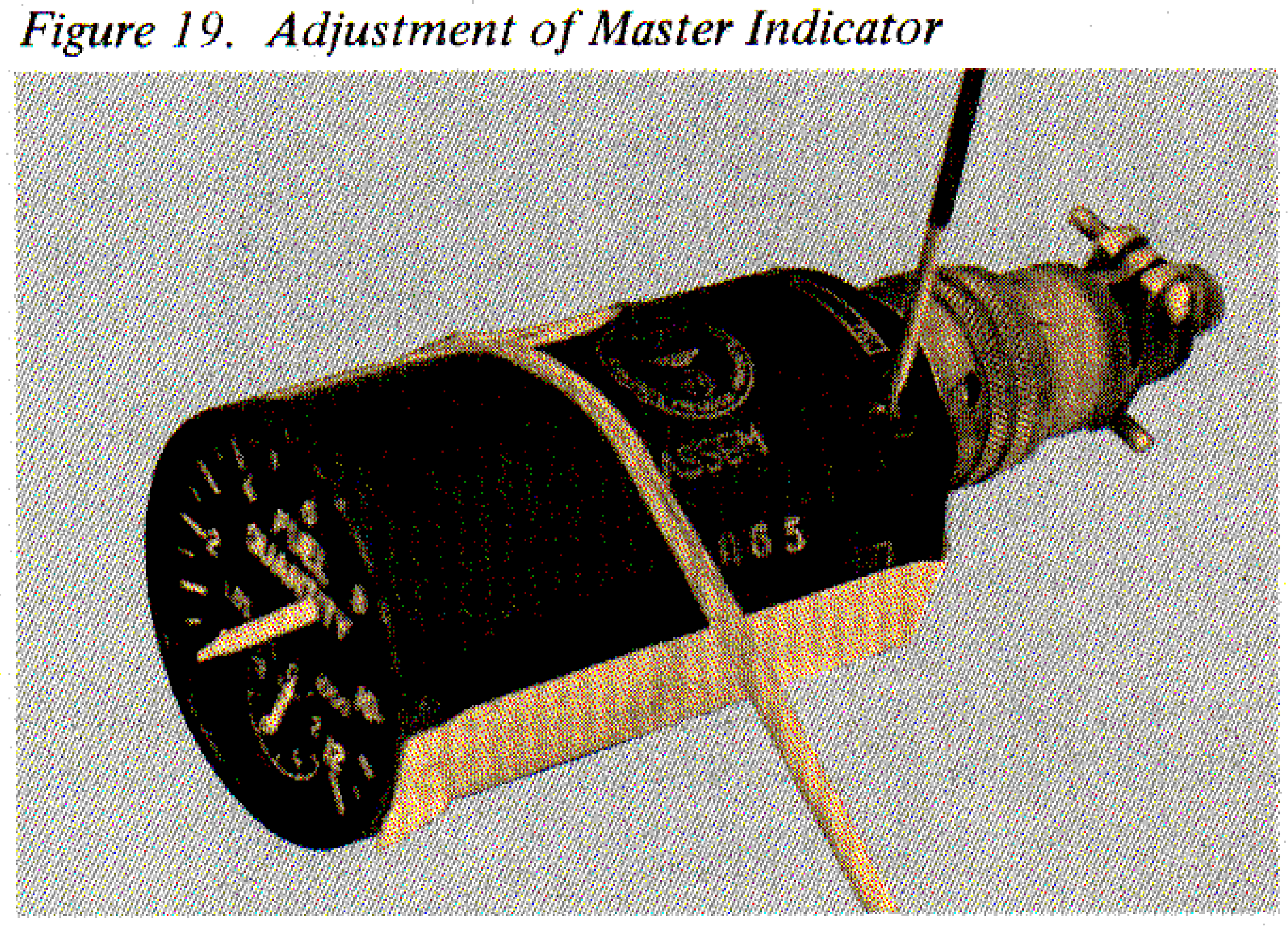
29. Place FUNCTION SELECTOR switch (24) to TEST INDIC-COMP SET position, and RANGE SELECTOR switch (6) to X1 position.

30. Loosen clamp (23), rotate COMP 25-250 MMF simulator (22) until logged COMPEN FULL value is indicated on CAPACITANCE INDICATOR (7), then tighten clamp (23).

31. Place RANGE SELECTOR switch (6) to X3 position, and FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position.

32. Loosen clamp (26), rotate PROBE 25-250 MMF simulator (27) until logged capacitance of TANK EMPTY units is indicated on CAPACITANCE INDICATOR (7), then tighten clamp (26). (Divide logged capacitance value by 3 before inserting value with simulator.) Use extreme care with this adjustment.

Figure 19. Adjustment of Master Indicator



33. Set FUNCTION SELECTOR switch (24) to TEST INDIC-TEST position. Master and repeater indicators shall read zero.

34. Place FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position, RANGE SELECTOR switch (5) to X10 position, and PROBE MMF switch (28) to 200 for tank units in either No. 1, 2, 3, or 4 tanks, or to 400 for tank units in No. 5 tank. Loosen clamp (26), rotate PROBE 25-250 MMF simulator (27) until logged TANK FULL capacitance value is shown on CAPACITANCE INDICATOR (7), then tighten clamp (26).

35. Place FUNCTION SELECTOR switch (24) to TEST INDIC-TEST position. Master and repeater indicators shall drive to full position; if not, adjust the FULL adjustment screw at the rear of the master indicator until the full mark is reached (12,000 pounds for tanks No. 1, 2, 3, or 4, and 19,000 pounds for tank No. 5); repeat "full" adjustment on repeater indicator. Press TEST switch; master and repeater indicators shall travel down-scale. Release TEST switch; indicators shall return to full reading.

36. Repeat steps 22, 23, and the first part of step 24 to check for zero. If the indicator requires excessive adjustment, the "full" end of the scale must be rechecked.

37. Open and tag FUEL QUANTITY INDICATOR circuit breaker for system under test.

38. To recheck zero reading, disconnect B952 Adapter Cable from master indicator and aircraft harness, then reconnect indicator to aircraft harness.

39. Remove tag and close FUEL QUANTITY INDICATOR circuit breaker opened in step 37.

40. Note that indicator shall drive to the zero reading.

41. Turn off power to TF-20-1 test set and aircraft. Disconnect and remove the three adapter cables from the test set and aircraft wiring. Install the master and repeater indicators in their respective instrument panels. Secure the test equipment. Remove external power from the aircraft.

Wet Tank Calibration Although greater accuracy can be attained by calibrating the fuel quantity indicating system indicators when the fuel tanks are dry, circumstances may make defueling impractical or impossible. If this is the case, the wet tank procedure must be used. During this procedure empty and full tank capacitance values are simulated with the TF-20-1 test set. As with dry tank calibration, it is preferable that the capacitance values employed during instrument calibration be values that have been measured and logged for that particular aircraft. However, if such measurements are not available, or if system components have been replaced (thereby rendering logged values invalid), the nominal values shown in Figure 16 may be used. Since it is recommended that wet-tank indicator calibrations be cross-checked with manual fuel measurements, the aircraft must be positioned at the one degree nose-down and laterally level attitude. Proceed with the wet tank calibration procedure as follows:

WARNING

The aircraft MUST be grounded to earth during calibration or capacitance measurement of the fuel quantity indicating system to minimize a hazard from sparks in the aircraft fuel tanks.

1. Connect an external source of 115-volt, 400 Hz ac power to the aircraft.

2. Place EXTERNAL POWER switch on flight station right inboard overhead panel ON.

3. Close the following circuit breakers:

   a. FUEL QUANTITY INDICATORS-MONITORABLE ESSENTIAL AC

BUS (Forward Load Center).

b. FUEL QTY SYS TEST-EXTENSION MAIN DC BUS (Forward Load Center).

c. FUEL QTY IND FUELING PNL-MAIN AC BUS A (Main Load Center).

4. Connect F12076-603 Power Cable to TF-20-1 test set receptacle (4) and to 115-volt, 400 Hz ac aircraft utility outlet on Rack A in the flight station.

5. Place test set power switch (1) to ON position.

6. Check that power light (2) is illuminated.

NOTE

Allow test set to warm up for a minimum of five minutes before using set.

7. Open and tag the FUEL QUANTITY INDICATOR circuit breaker of circuit under test.

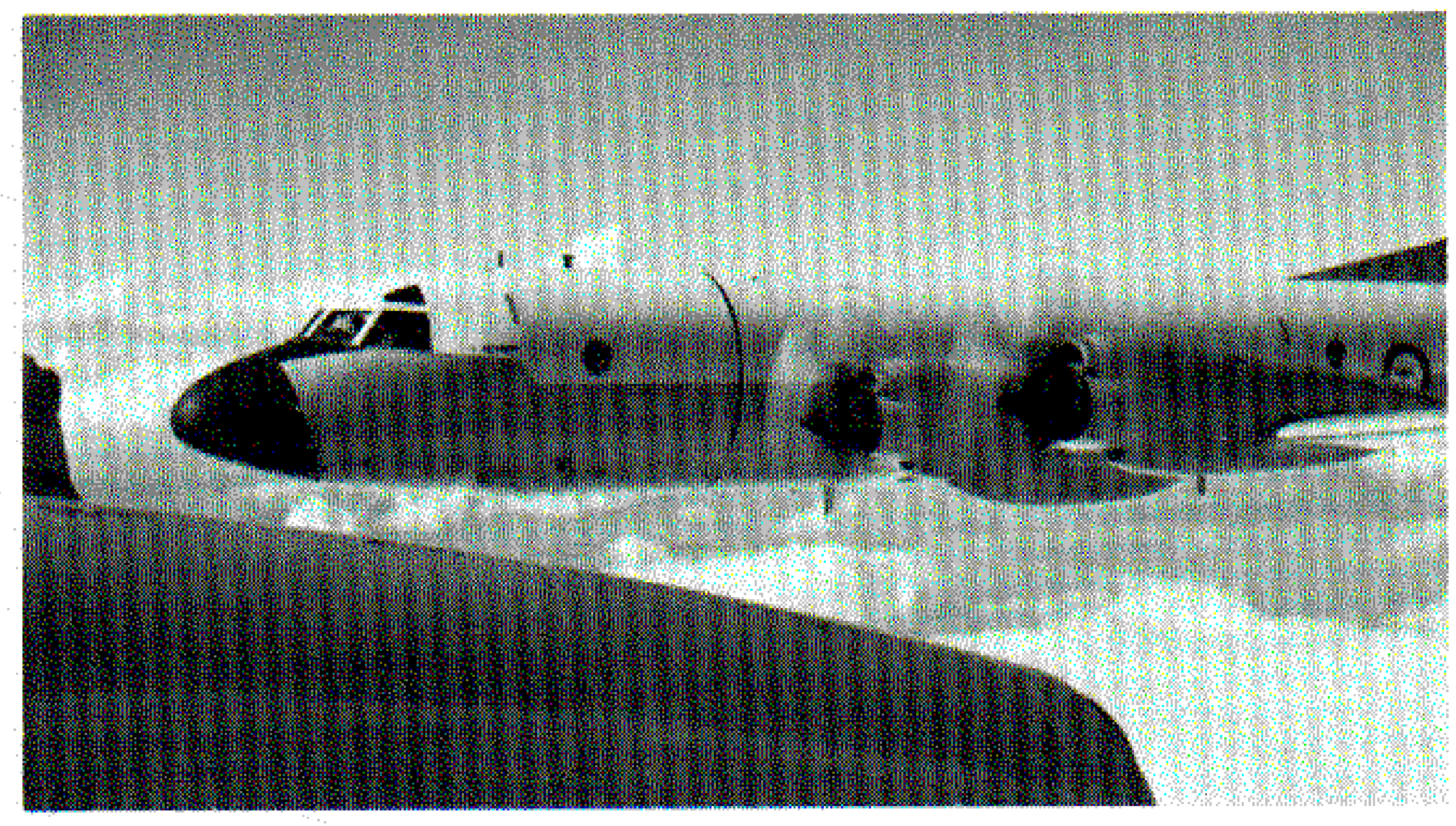
8. Check B952 Adapter Cable for physical damage, broken or bent connectors, or cracked insulation. Correct any faults with the cable before proceeding with the next step.

9. Connect B952 Adapter Cable to test set as follows:

a. Connect adapter cable TANK UNIT lead P5/COMP to (10) on test set, P6/COAX to (11), and P7/UNSH to (12).

b. Connect adapter cable TEST IND lead P2/UNSH to (20) on test set, P3/COAX to (19), and P4/COMP to (21).

10. Remove master indicator of tank under test from the Fuel Management Panel, and uncouple the connector from the



indicator. Connect the B952 Adapter cable plug P1 to the indicator, and plug P8 to the aircraft wiring harness.

11. Connect B515 Safety Grounding Cable to the fuel quantity indicating system wiring by connecting one spring clip to the harness plug of the indicator under test, the spade lug to (5) on the test set, and the other spring clip to the pilots seat track.

12. Remove tag and close circuit breaker opened in step 7.

13. Establish aircraft ICS communications between personnel at flight station and Fueling Panel.

14. Remove matching repeater indicator of system under test from Fueling Panel, but do not uncouple indicator from system wiring.

15. Calibrate TF-20-1 test set in accordance with instructions shown in Figure 18. These instructions are extracted from the NAVAIR 01-75PAA-2-4 Maintenance Instruction Manual. Disregard instructions on the general instruction placard furnished with the TF-20-1 test set except those coinciding with the instructions shown on Figure 18.

16. Place FUNCTION SELECTOR switch (24) to TEST INDIC-COMP SET position, and RANGE SELECTOR switch (6) to X1 position.

17. Loosen clamp (23), rotate COMP 25-250 MMF simulator (22) until logged (or

nominal) COMPEN FULL value is indicated on CAPACITANCE INDICATOR (7), then tighten clamp (23). (Compensation value does not affect empty calibration.)

18. Place RANGE SELECTOR switch (6) to X3 position, and FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position.

19. Loosen clamp (26), rotate PROBE 25-250 MMF simulator (27) until logged (or nominal) capacitance value of TANK EMPTY units is indicated on CAPACITANCE INDICATOR (7), then tighten clamp (26). (Divide logged capacitance value by 3 before inserting value with simulator.) Use extreme care while making this adjustment.

20. Place FUNCTION SELECTOR switch (24) to TEST INDIC-TEST position. Master and repeater indicators shall read zero. If not, adjust EMPTY adjustment screw at the rear of the master indicator first until the pointer indicates zero; then adjust repeater indicator to zero. Press TEST switch on Fuel Management Panel; indicators shall travel down-scale. Release TEST switch; indicators shall return to zero.

21. Place FUNCTION SELECTOR switch (24) to TEST INDIC-PROBE SET position, RANGE SELECTOR switch (6) to X10 position, and PROBE MMF switch (28) to 200 for either No. 1, 2, 3, or 4 tanks, and to 400 for No. 5 tank. Loosen clamp (26), rotate PROBE 25-250 simulator (27) until logged (or nominal) TANK FULL capacitance value is read on CAPACITANCE INDICATOR (7), then tighten clamp (26).

22. Place FUNCTION SELECTOR switch (24) to TEST INDIC-TEST position. Master and repeater indicators shall drive to a full reading of 12,000 lb for either No. 1, 2, 3, or 4 tanks, or 19,000 lb for No. 5 tank. If not, adjust FULL adjustment screw at the rear of the master indicator until the full quantity is indicated; then adjust repeater indicator to full. Press TEST switch on Fuel Management Panel; indicators shall travel down-scale. Release TEST switch; indicators shall return to full reading.

23. Repeat steps 18, 19, and 20 to recheck zero reading.

24. Open and tag circuit breakers of system under test. Turn off power to TF-20-1 test set and aircraft. Disconnect and remove the three adapter cables from the test set, aircraft wiring, and master indicator. Reconnect aircraft wiring to master indicator. Install master and repeater indicators. Secure test equipment. Remove tags and close circuit breakers. Remove external power from aircraft.

TOTALIZER CALIBRATION AND ADJUSTMENT

Whenever a tank probe unit is replaced, or whenever a tank indicator or fuel totalizer is replaced or adjusted, the totalizer will require calibration and adjustment. Like the fuel quantity indicators, the totalizer has EMPTY and FULL adjustment screws at the rear of the instrument.

Totalizer calibration and adjustment requires an external source of 115-volt, 400 Hz ac power to energize the aircraft electrical system. The F12076-300 totalizer calibrator shown in Figure 15 is used to calibrate the totalizer indicator. Calibrate the fuel totalizer as follows:

WARNING

The aircraft MUST be grounded to earth during calibration or capacitance measurement of the fuel quantity indicating system to minimize a hazard from sparks in the aircraft fuel tanks.

1. Open and tag all fuel quantity indicating system circuit breakers.

2. Remove all five master indicators from the Fuel Management Panel.

a. Mark each indicator with its appropriate tank number.

b. Secure the wiring harness with cord as each indicator is removed from the panel and before the indicator is disconnected from the harness. (If more than one indicator is disconnected from its wiring harness at the same time, it is possible to transpose fuel quantity indicating circuits or to lose one of the harnesses under the Fuel Management Panel.)

3. Uncouple the wiring connector from the No. 1 indicator; connect tank No. 1 cable from the F12076-300 totalizer calibrator to the connector just removed from the No. 1 indicator and the No. 1 indicator.

4. Repeat step 3 for each master tank indicator, using the appropriate lead of the F12076-300 test set.

5. Remove the totalizer from the fuel management panel, but do not disconnect the totalizer from the aircraft wiring.

6. Remove tags and close the circuit breakers opened in step 1.

7. Adjust each control of the F12076-300 totalizer calibrator so that each master indicator reads exactly zero.

8. Turn the EMPTY adjustment screw on the totalizer indicator until the totalizer reads exactly zero.

9. Adjust each control of the F12076-300 totalizer calibrator so that the master indicators for tanks Nos. 1, 2, 3, and 4 read exactly 12,000 pounds and the master indicator for tank No. 5 reads exactly 19,000 pounds.

10. Turn the FULL adjustment screw on the totalizer indicator until the totalizer reads exactly 67,000 pounds.

11. Depress the FUEL GAGE TEST switch on the fuel management panel. This shall cause all indicators to travel down scale.

12. Release the FUEL GAGE TEST switch. All indicators shall return to their original settings.

13. Recheck the indicator "empty" settings. If it is necessary to adjust the full or empty setting of a master indicator, it will be necessary to repeat the calibration and adjustment procedures for the master indicator and its repeater indicator. If it is necessary to adjust the totalizer "empty" setting, recheck and adjust the "full" setting as required until proper totalizer calibration has been achieved.

14. Open and tag the circuit breakers closed in step 6.

15. Reinstall the totalizer indicator in the Fuel Management Panel.

16. Disconnect tank No. 1 cable of F12076-300 totalizer calibrator from the aircraft wiring and tank No. 1 master indicator; recouple the aircraft wiring to tank No. 1 master indicator; reinstall tank No. 1 master indicator in the Fuel Management Panel. Repeat for the other four master indicators, bearing in mind that if more than one wiring connector and its master indicator are uncoupled from the test set cables coincidentally, transposition of fuel quantity indicating circuitry is possible or a loose wiring harness can be lost beneath the Fuel Management Panel.

17. Remove the tags from the circuit breakers opened in step 14 and close the circuit breakers. Secure test equipment. Remove external power from aircraft.

SYSTEM INSULATION RESISTANCE CHECK The overall condition of system circuitry can be determined by performing a system insulation resistance check. If the system insulation resistance is below established minimum values, it is indicative that there is a defect in the system wiring or in one or more of the tank quantity probes. Low insulation resistance will cause the system to indicate that there is more fuel in the tank than is actually aboard.

The following procedures are used to check the insulation resistance of the fuel quantity indicating system circuitry from the test set intercept point in the flight station to the probe installations in the fuel tank. Accuracy of these measurements is contingent on the tank of the system undergoing check being *completely* dry. Prior to setting up the test equipment, the technicaian must *be certain* that the aircraft is earth grounded to minimize a spark hazard in the fuel tanks, then proceed as follows:

1. Connect external source of 115-volt, 400 Hz ac power to the aircraft.

2. Place EXTERNAL POWER switch on flight station right inboard overhead panel ON.

3. Connect F10276-603 Power Cable to (4) on TF-20-1 test set and to 115-volt, 400 Hz ac aircraft utility outlet on rack A in the flight station.

4. Open and tag circuit breaker for system under test.

5. Connect B952 Adapter Cable to test set as follows: Connect TANK UNIT lead P5/COMP to (10) on test set, P6/COAX to (11), and P7/UNSH to 12. *Do not connect the B952 TEST IND connectors to the test set TEST INDIC connections.*

6. Remove the master indicator of the system under test from the Fuel Management Panel, and uncouple aircraft wiring connector from indicator. Connect B952 Adapter Cable Plug P1 to the indicator and plug P8 to the aircraft wiring harness.

7. Connect B515 Safety Grounding Cable to the fuel quantity indicating system by connecting one spring clip to the indicator harness plug of the system under test, the spade lug to (5) on test set, and the other spring clip to the pilots seat track.

8. Place test set power switch (1) to ON position.

9. Check that power light (2) is illuminated.

NOTE

Allow the test set to warm up for five minutes before using set.

10. Calibrate the test set MEGOHMMETER (16) according to instructions shown in Figure 18. These instructions are extracted from the NAVAIR 01-75PAA-2-4 Maintenance Instruction Manual. Disregard instructions on the general instruction placard furnished with the TF-20-1 test set except those coinciding with the instructions shown on Figure 18.

11. Check A lead to B lead.

    a. Place TF-20-1 test set CAP-RES CHECK switch (13) to MEGOHMS A-C/A-B position.
    b. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-UNSH position.
    c. Place RANGE SELECTOR switch (17) to a position that provides a reading on the MEGOHMMETER (16) closest to the mid-scale position.
    d. The minimum resistance of the fuel quantity-indicating units in tanks 1, 2, 3, or 4 shall be 400 megohms, and of the units in tank 5 the minimum resistance shall be 300 megohms.

12. Check A lead to C lead.

    a. Place CAP-RES CHECK switch (13) to MEGOHMS A-C/A-B position.
    b. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-COMP position.
    c. Place RANGE SELECTOR switch (17) to a position that provides a

reading on the MEGOHMMETER (16) closest to the mid-scale position.

d. The minimum resistance shall be one megohm.

13. Check C lead to ground.

a. Place CAP-RES CHECK switch (13) to MEGOHMS C-GND/B-GND position.
b. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-COMP position.
c. Place RANGE SELECTOR switch (17) to a position that provides a reading on the MEGOHMMETER (16) closest to the mid-scale position.
d. The minimum resistance shall be one megohm.

14. Check B lead to ground.

a. Place CAP-RES CHECK switch (13) to MEGOHMS C-GND/B-GND position.
b. Place FUNCTION SELECTOR switch (24) to TANK UNIT TEST-UNSH position.
c. Place RANGE SELECTOR switch (17) to a position that provides a reading on the MEGOHMMETER (16) closest to the mid-scale position.
d. The minimum resistance shall be one megohm.

WARNING

Be certain that power to the TF-20-1 test set is OFF when connecting or disconnecting fuel quantity indicator and aircraft wiring harness.

15. Turn off power to the TF-20-1 test set and the aircraft. Disconnect the adapter, power, and grounding cables from the test set, aircraft wiring, and master indicator. Reconnect the aircraft wiring to the indicator, then reinstall the indicator in its panel. Secure the test equipment. Disconnect the external power source from the aircraft.

MANUAL FUEL MEASUREMENT

The electronic system is the primary fuel measuring system, for it adapts automatically to variations in both aircraft attitude and fuel density. In addition to the electronic system, there are two alternative means of measuring fuel quantity in the P-3—a hydro-static pressure tester and the conventional dip-sticks (including a bottom-mounted sight gage for No. 5 Tank). Since the capabilities and limitations of the three measuring methods may not be generally appreciated, we will discuss these factors briefly to show why a given tank yields different readings when measured by different means.

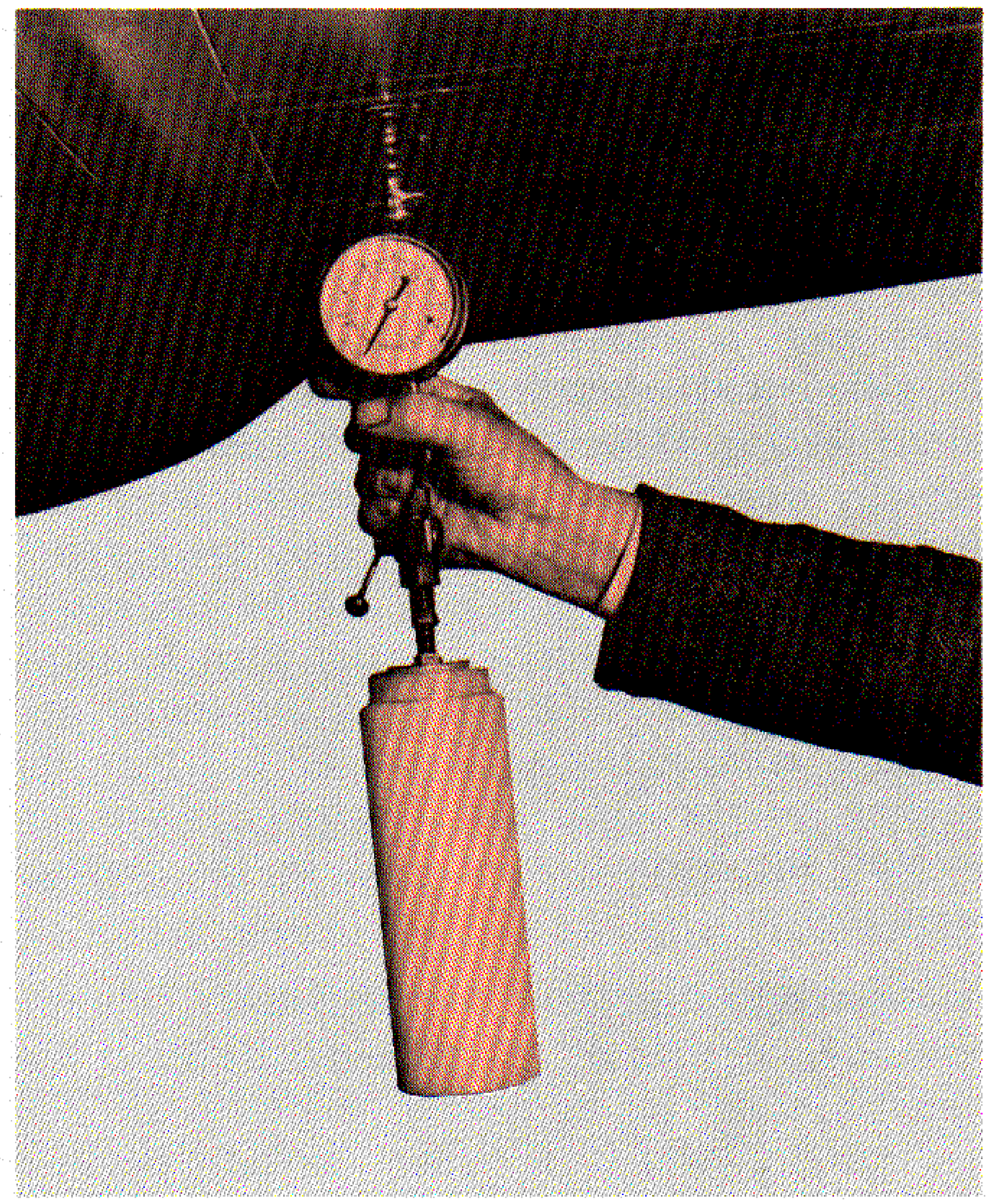


Figure 20. Hydro-Static Fuel Gage

HYDRO-STATIC GAGE The hydro-static gage shown in Figure 20 measures the hydro-static pressure of fuel in any wing tank at the water drain valve, which is the lowest point in the tank. The gage is designed for use at environmental temperatures between -17.8^{o} and 54.4^{o}C (0^{o} and 130^{o}F), and at altitudes between sea level and 7,000 feet. It is calibrated to measure fuel in the specific gravity range of JP-5, although it may be used for JP-4. An off-level aircraft attitude severely degrades hydro-static gage accuracy, with roll having a greater affect than pitch and causing significant error. Upon completion of fuel quantity measurement with the hydro-static gage, take the opportunity to examine the fuel in the gage bottle before disposing of it to determine if the fuel is contaminated or if there is water in the tank.

Hydro-static gages now entering service are equipped with a new extension seal fabricated from B-44-3 Tygon tubing in place of the impregnated glass cloth, wire-wound extension seal formerly furnished with the gage. Extension seals made from Tygon tubing will be available as spares for hydro-static gages now in service.

The following procedure is an example of the degree of accuracy that may be reasonably expected from a cross-check of the P-3 fuel quantity indicating system with dip stick and sight gage measurements in the fuel tanks. This procedure is part of Lockheed Flying Operations Department's P-3C SATP No. 29 (System Acceptance Test Procedure) that must be satisfied before the aircraft will be accepted from production. If the results fall outside the limits specified in the procedure, recalibration of the aircraft fuel quantity indicating system is required. The aircraft must be laterally level in the one-degree nose down position for the dip stick and sight gage readings.

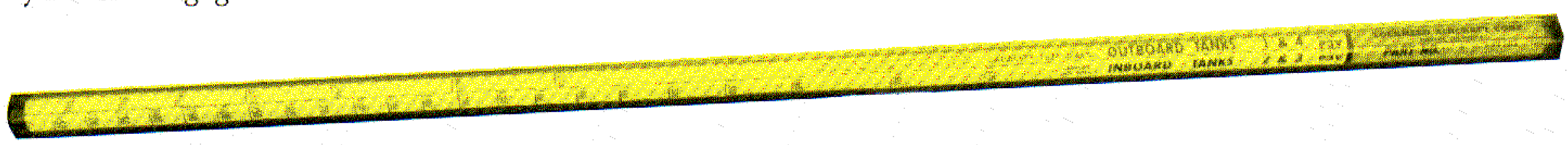


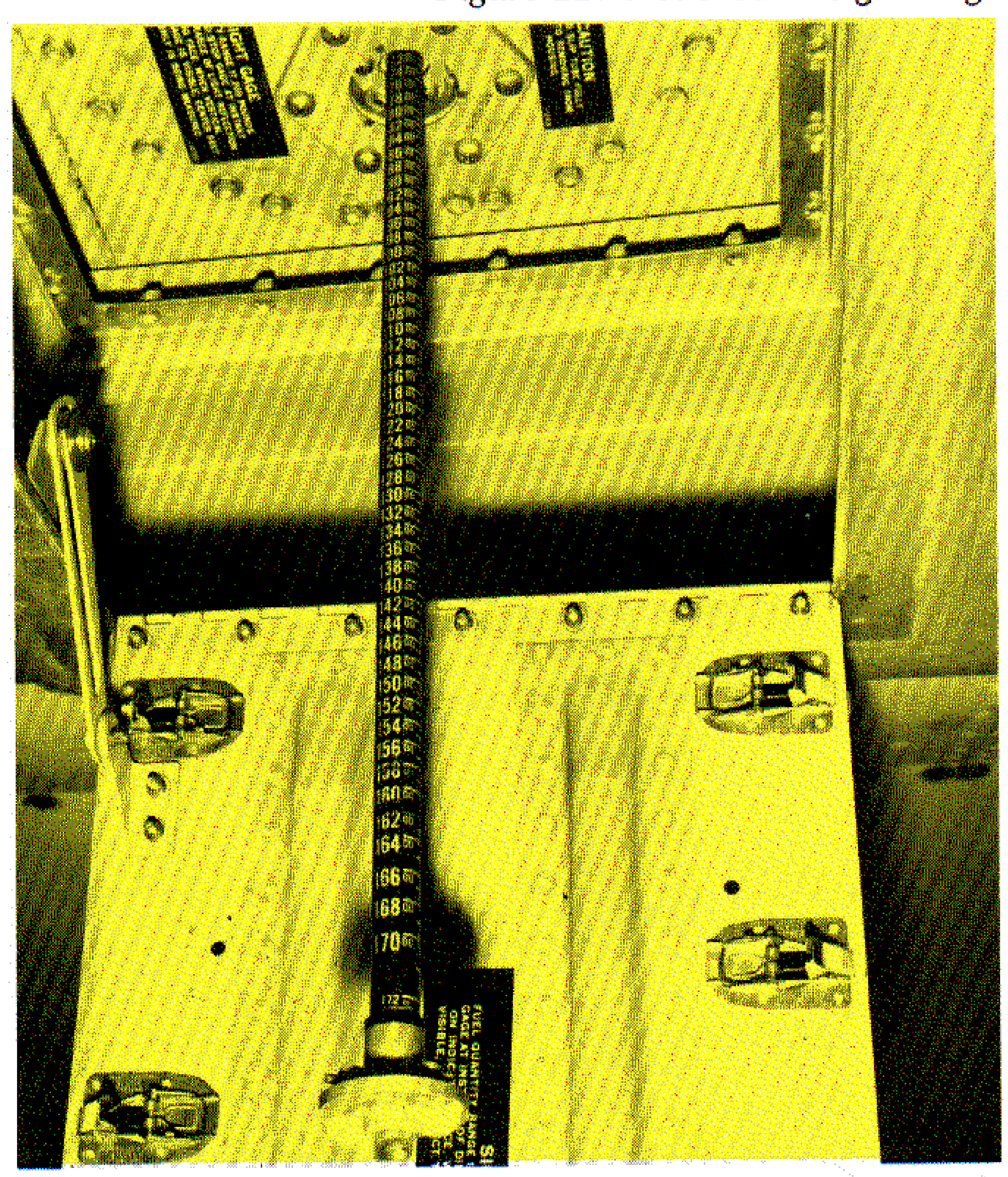
Figure 21. Wing Tank Dip Stick

DIPSTICK AND SIGHT GAGE The wing tanks dip stick is marked in gallons, while the No. 5 tank sight gage is calibrated for JP-4 fuel at 6.5 lb/gallon and marked in pounds to provide a direct reading. However, the No. 5 tank sight gage actually measures volume, not weight. Wing tank fuel quantity cannot be measured by the dip-stick (Figure 21) if the level is low, and the fuel level in the dual-compartment No. 5 tank must be above the interconnect tube between the center and fuselage compartments (about 4000 lb) or the reading on the sight gage (Figure 22) will not include the increment of fuel in the fuselage compartment.

MANUAL MEASUREMENT, PRO AND CON Manual measuring devices are simpler and more direct than the electronic gaging system, and they are convenient for situations where aircraft electrical power is not readily available. Manual measurements should be made frequently and routinely as a safeguard against grossly inaccurate fuel provisioning, but good judgment must be exercised in use of the information obtained. A wide discrepancy between a manual and electronic indication is to be expected in some situations, and corrective action should not be initiated unless a careful analysis of the situation shows that the electronic system, not the manual measurement, is in error.

1. Measure fuel quantity in tanks 1, 2, 3, and 4. Record (gallons).
2. Multiply these gallon readings by 6.5 lb for JP-4, 6.7 lb for JET A, or 6.8 lb for JP-5, and record.
3. Read tank 5 sight gage. Record (lb).

Figure 22. No. 5 Tank Sight Gage



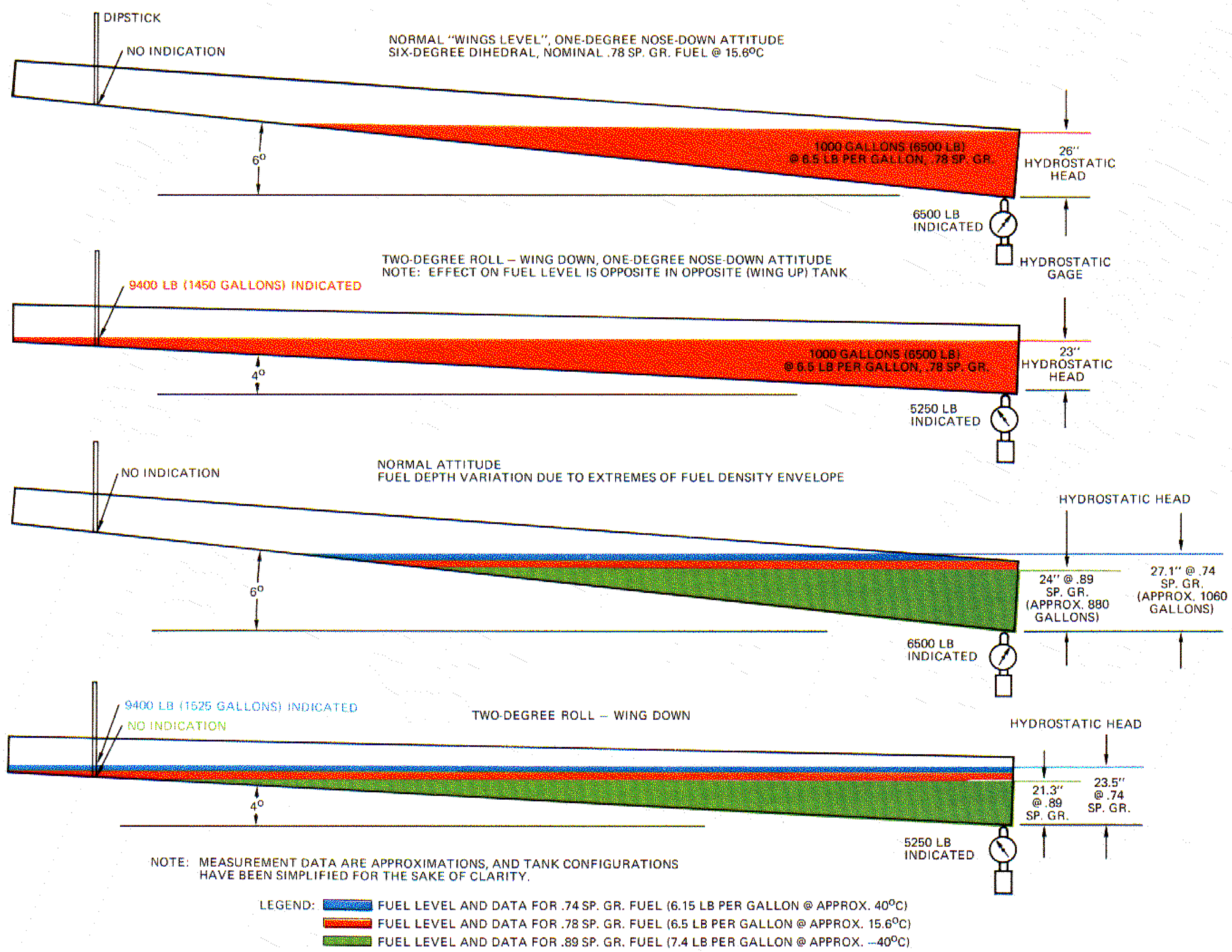


Figure 23. Effect of Aircraft Attitude and Fuel Density on Manual Fuel Measurement

NOTE

Tank 5 sight gage is calibrated for JP-4 at 6.5 lb/gal. Use the following correction factors for tank 5 sight gage when fuel other than JP-4 is used:

Add 0.2 lb/gal for JET A (or multiply reading by 1.03); add 0.3 lb/gal for JP-5 (or multiply reading by 1.046).

4. Read Fueling Panel gage quantities and record.

5. Read flight station gage quantities and record.

6. Read flight station totalizer and record. Cross-check limits are:

   a. Difference between flight station and Fueling Panel gages for each tank shall not exceed 100 lb.
   b. Difference between dipped quantity and Fueling Panel and/or flight station gages for each tank shall not exceed 500 lb.
   c. Difference between total of flight station gages and totalizer shall not exceed 500 lb.

Figure 23 portrays common causes of discrepant indications in readings taken manually. The Orion's shallow, sloped, 30-ft. long outboard tanks present the most severe problems in manual measurement, and large-volume tanks such as these provide the possibility for proportionately large-scale measurement errors. Data in Figure 23 are approximations, simplified to illustrate clearly the effect of off-level aircraft attitude and deviations in fuel density from the "normal" 6.5-lb/gallon, average for JP-4 at 60°.

Other factors not portrayed in Figure 23 also enter into the problem of assessing validity of hydro-static pressure readings, chiefly the accuracy of the hydro-static test gage. These gages translate exceedingly small pressure variations into large weight indications on a small-diameter, 270° scale. Consequently, a minute gage error can produce a vast deviation from true in gage reading. Indeed, the tolerance of hydro-static gage measurements is actually 1200 lb per tank. The gage must be protected from abuse, and should be calibrated regularly in accordance with the procedure given in the NAVWEPS 01-75PAA-2-4 Maintenance Instruction Manual. Hydro-static pressure readings have no validity if the tank is not freely vented to atmosphere. If a tank is full or is tilted wing-down sufficiently to submerge the float vent-valve at the outboard end, some degree of either positive or negative pressure will almost certainly exist in the tank, invalidating the hydro-static gage reading. Positive internal pressure is most common, and usually it will drive the gage off-scale. The tank pressure relief valves are set to open at 1.2 psi, and the gage incorporates a mechanical stop to protect the mechanism against over-pressurization damage of this order (about 100%). If the gage is connected to *any* pressure source other than the fuel tank water drain, extreme care must be taken to ensure against over-pressurization. ▲▲

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