the GENERAL RADIO Experimenter

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A CALIBRATOR FOR AIRCRAFT FUEL GAGES

Also IN THIS ISSUE

Anyone who has been forcibly made aware of the vagaries and inaccuracies of gasoline gage indicators by running out of gas in some remote spot in his car will have no difficulty in understanding why aircraft fuel gages have been made more accurate, even at the cost of considerable complication. For the motorist, running out of gas is at most an inconvenience, rarely a matter of life and death as it could be to the flier.

Until 1943, most airplanes made use of float-type fuel gages.[1] A float in each tank actuated a rheostat, and a meter, indicating the current traversing the rheostat, had a dial calibrated in amount of fuel. While it was possible to totalize the fuel in several tanks and do other desirable operations with a float-type system, the method suffered for lack of flexibility and never remotely approached the accuracy and durability of a capacitance null-type device.

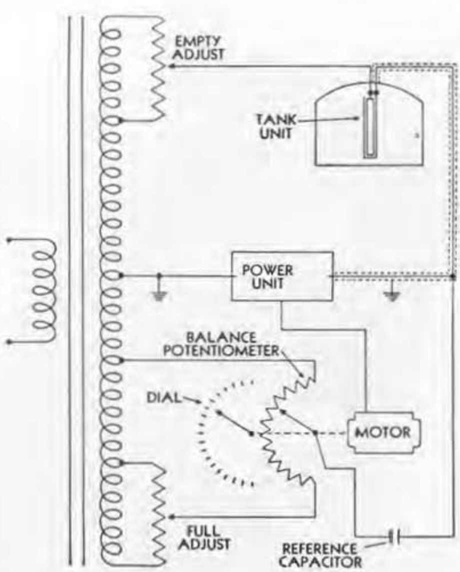
Despite all these disadvantages, the float-type fuel gages went unchallenged for a couple of decades. Finally, during World War II, capacitance-type indicating equipment first appeared. The early versions showed improved flexibility over float-type systems but still made use of a quantity-indicating meter. The final devising of a null-balanced capacitance-type fuel gage using a

[1] Some vertical-tube sight gages were also used but were not satisfactory under flight conditions.

Figure 1. View of the Type P-579 Field Variable Capacitance Tester, mounted in its transit case.

servo-balanced 400-cycle bridge introduced a system having both the accuracy and flexibility of those at present in use, manufactured by four firms, namely, Avien, Liquidometer, Minneapolis-Honeywell, and Simmonds Aerocessories.

As an example, Figure 2 illustrates schematically the self-balancing bridge circuit basic to the Minneapolis-Honeywell product. This system was developed in 1944 by Minneapolis-Honeywell Regulator Company. One can see in this figure portions of the circuit essential to this article, namely, the TANK UNIT, the EMPTY ADJUST and FULL ADJUST potentiometers, and the DIAL. Necessarily, the DIAL must be made to read properly at both ends of its scale. To bring this about, the EMPTY ADJUST potentiometer is set to DIAL zero when the TANK UNIT is replaced by a capacitance of proper value for empty tank. With full tank simulating capacitance in place of TANK UNIT, FULL ADJUST potentiometer is set to make DIAL read proper maximum.



An inaccurate system does not demand very much of its testing equipment. With an accurate system, of course, the converse is true. If the system's inherent accuracy is to be realized, it must be very carefully installed and adjusted in each airplane. Minneapolis-Honeywell early recognized the need, both military and commercial, for precise equipment to use in lining up their fuel gage equipment, both at time of installation and for routine maintenance purposes. It is obvious to even the most casual observer that it is impractical to set the FULL and EMPTY positions of the indicator by repetitively filling and emptying the various tanks involved.

The logical alternative was to provide standard capacitors which would simulate the EMPTY and FULL capacitances of the sensing units in the tanks. Since these capacitance values might be different for each tank, the number of different capacitance standards required could be enormous, and continually growing. This could be avoided by the use of an adjustable capacitor, if one could be obtained having accuracy sufficient for the job.

It was at this point that the collaboration between Minneapolis-Honeywell and General Radio began on the development of what ultimately became the Type 0-3 Field Variable Capacitance Tester, which is described in specification MIL-T-5911A. A Type 722 Capacitor with appropriate modifications would meet requirements nicely. Figure 3 illustrates the parts which were manufactured by General Radio for inclusion by Minneapolis-Honeywell in their HT-109 Tester, a device meeting the requirements for the 0-3. Included are

Figure 2. Schematic diagram of the capacitance null-type fuel gage, employing a self-balancing bridge. (Minneapolis-Honeywell)

three-terminal capacitors, variable and fixed, and a three-terminal connector accepting the plug-in range-extending fixed mica capacitors.

Eventually other manufacturers of 0-3 Testers of their own designs were supplied variable and fixed capacitors and three-terminal connectors by General Radio. These included The Jackson Electrical Instrument Company and Monument Engineering Company.

As experience with the Type 0-3 Testers slowly piled up, it became apparent that some changes could be made which would improve the convenience of use. One of these changes consisted of eliminating the loose external plug-in range-extending capacitors and substituting for them switched capacitors within the instrument. Some of the 0-3 types had this feature. The other desirable change was to substitute coaxial connectors for the three-binding-post arrangement. By maintaining the coaxial shielding unbroken, measurement errors and inconsistencies could be avoided. This change never appeared on the 0-3, but became a feature of its successor, the MD-1.

A more cogent reason appeared for obsoleting the 0-3, namely, the ubiquity of the jet plane. Practically every military base would have to service such planes with their more complicated fuel-indicating systems.

Why must they be more complex? Because jet fuel indications in the older, simple systems are dependent on both fuel composition and temperature. Aviation gasoline, for reciprocating engine craft, gives quantity indications (in pounds rather than gallons) essentially independent of source and temperature. Its composition, and consequently its dielectric constant, are essentially uniform from refinery to refinery. It happens that the expansion in volume on heating is just balanced by the reduction in dielectric constant. Thus a given weight of fuel gives the same capacitance in the tank sensing element and hence the same dial reading, almost regardless of the temperature.

Jet fuel on the other hand, is not a homogeneous, approximately single chemical compound, but almost any sort of a mixture within a wide range of hydrocarbon combustibles, depending on where and when it was refined. It exhibits relatively broad variations in dielectric constant and density. Jet fuel indications with simple systems, therefore, had appreciable composition and temperature variations. Hence jet fuel systems had to include an added fixed sensing element in the bottom of each tank to introduce an appropriate correction into the bridge circuit of the indicator. This meant that another precision variable capacitor would be needed in the tester, since the system during calibration could indicate and be adjusted properly only if it had attached to it simulating capacitors for both sensing and compensating units.

This, then, brings us to the Type MD-1 Field Variable Capacitance Tester, described in specification MIL-T-

Figure 3. Elements supplied by the General Radio Company for the 0-3 Tester built by Minneapolis-Honeywell Regulator Company.

Figure 4. Connectors supplied with the Type P-579 Tester for connecting it to the many types of fuel gages now in use.

8579, which was prepared at the Wright Air Development Center of the Air Research and Development Command. Its essential differences from one or more of the predecessor 0-3 Testers were: first, the added variable capacitor; second, the internally switched range-extending capacitors; and third, the three mutually different Minneapolis-Honeywell coaxial connectors. Over the past several years, General Radio developed the new precision capacitor, which had to be direct reading (that is, linear) down to 10$\mu\mu$f, and, following the completion of that development, built and submitted samples of an MD-1 to MIL-T-8579 for qualification testing. Following completion of qualification tests late in September of 1954, production was immediately expedited so that early shipments could be made to meet the urgent needs of a number of the air-frame manufacturers.

This instrument, known as General Radio Type P-579 Field Variable Capacitance Tester and illustrated in Figures 1, contains, in addition to what has been mentioned before, a number of cables and tee adapters, illustrated in Figure 4, to enable it to be connected for measurement purposes to any of the existing fuel gage systems in military planes now flying. The capacitors are mounted in a moisture-resistant aluminum case having a removable desiccant cartridge, and this case is shockmounted inside a transit case. The transit case, also of aluminum, contains a compartment for stowing the cables and on the lid a holder into which is slipped the correction chart for the capacitors, laminated into 40-mil-thick clear plastic.

It is expected that Type P-579 Testers will be in stock for prompt shipment by about the middle of September 1955. They will be available for commercial or military use, and can be supplied with or without Government inspection at our plant. Detailed specifications of the equipment, which are quite lengthy, may be obtained upon request. They indicate the performance of the various capacitors included and describe the environmental and other tests which the product will meet.

— P. K. McElroy

MORE NEW COAXIAL PARTS

In addition to the new Type 874 Coaxial Elements described in the August issue of the Experimenter, the following items are now available.

RIGID-LINE ADAPTORS

A low-reflection adaptor from Type 874 Connectors to 7/8″ 50.0-ohm UHF Rigid Air Line and an adaptor to 1 5/8″ 50.0-ohm UHF Rigid Air Line are now available. The VSWR's of pairs of these units are shown in Figure 7. These adaptors provide low-reflection means of making connections to the newer 50.0-ohm u-h-f lines. The u-h-f adaptors are fitted with a flange and an anchor terminal assembly containing a Teflon bead as shown in Figure 8. With these adaptors and GR coaxial measuring equipment, many types of measurements including the determination of very low standing-wave ratios, can be made on rigid-line circuits.

Figure 8. Type 874-QU1 and QU2 Adaptors.

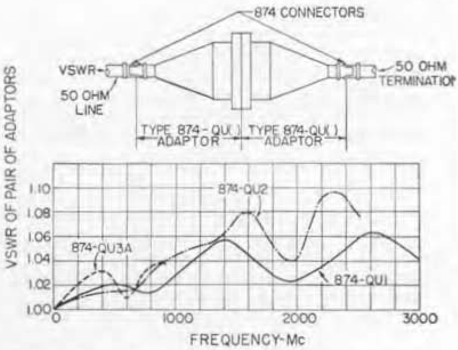


Figure 7. A plot of the VSWR as a function of frequency of pairs of adaptors from Type 874 Connectors to various sizes of 50.0-Ohm UHF Rigid Transmission Line.

SPECIFICATIONS

874-QU1
For use with: ⅞″ 50.0-ohm UHF rigid transmission line.
VSWR: less than 1.03 to 1000 Mc., less than 1.06 to 3000 Mc.
Net Weight: 8 ounces.

874-QU2
For use with: 1⅝″ 50.0-ohm UHF rigid transmission line.
VSWR: less than 1.03 to 1000 Mc., less than 1.06 to 2500 Mc.
Net Weight: 1 pound, 5 ounces.

Type		*Code Word*	*Price*
874-QU1	**Adaptor to ⅞″, 50-ohm, UHF Line..........**	COAXYUMBER	**$21.00**
874-QU2	**Adaptor to 1⅝″, 50-ohm, UHF Line.........**	COAXYUSHER	**46.00**

NEW PANEL CONNECTORS

A new type of panel connector is now available which mounts on the panel by means of four screws. These connectors can be installed closer together and are more easily removed than the older type.

Panel connector which mounts with four 4-40 screws, 13/16 apart. Size of flange is 15/16 square. ⅞″ diameter hole in panel required. Can be mounted either in front of or behind panel. Available to fit cables as shown in Table I. Net Weight: 2 ounces.

CABLE CONNECTOR FOR RG-9/U CABLE

In response to customer requests, a cable connector for use with Type RG-9/U Cable is now available. This connector can be supplied for mounting on the free ends of cables or on either the old or new types of panel mountings. Table I shows most of the cables which can be used with the Type 874 Cable Connectors now available. Armored cables can also be used with these connectors, but no provision is made for anchoring the armor. Net Weight: 2 ounces.

Figure 9. 874-PB Panel Connector.

TABLE I

Panel Connector Type	*Cable Connector Type*	*Cable Type* — *Matched*	*Cable Type* — *Unmatched*
874-PB	**874-C**	**874-A2**	**RG-7/U**
874-PB8	**874-C8**	**RG-8/U**	**RG-11/U,-63/U, -114/U,-133/U,-144/U**
874-PB9	**874-C9**	**RG-9/U,-87A/U,-116/U**	
874-PB58	**874-C58**	**RG-29/U,-55/U,-58/U, -141/U,-142/U**	
874-PB62	**874-C62**		**RG-59/U,-62/U,-71/U, -140/U**

U. S. Patent No. 2,548,457

Type		Code Word	Price
874-PB	Panel Connector...........................	COAXAPPLER	$2.50
874-PB8	Panel Connector...........................	COAXBATHER	2.50
874-PB9	Panel Connector...........................	COAXCANKER	2.50
874-PB58	Panel Connector...........................	COAXABATER	2.50
874-PB62	Panel Connector...........................	COAXBARKER	2.50

Type		Code Word	Price
874-C	Cable Connector...........................	COAXCABLER	$1.70
874-C8	Cable Connector...........................	COAXCORDER	1.70
874-C9	Cable Connector...........................	COAXCAMMER	1.70
874-C58	Cable Connector...........................	COAXCALLER	1.70
874-C62	Cable Connector...........................	COAXCANDER	1.70

IMPROVED UNIT CRYSTAL OSCILLATOR NOW AVAILABLE

The TYPE 1213-A Unit Crystal Oscillator[1] is a compact and inexpensive instrument providing frequency markers at 1 Mc, 100 kc and 10 kc intervals up to relatively high frequencies. The original design has now been slightly modified to improve performance with respect to line voltage fluctuation, and to increase the amplitude of the 1-Mc harmonics above 500 Mc. The improved instrument is designated as the TYPE 1213-AB Unit Crystal Oscillator.

In the original design, the panel frequency-setting adjustment was a capacitor in series with the crystal with the rotor off ground. This connection caused a small change in frequency when a metal screwdriver was touched to this adjustment for setting the crystal frequency, thus making a difficult task of setting to WWV with high precision. In the modified design, the capacitor in series with the crystal is retained as a coarse adjustment, while the panel control tunes the plate circuit of the crystal oscillator stage, thus giving a fine frequency adjustment with a grounded rotor.

Voltage regulation has been added to the oscillator stage in the form of a pair of gas regulator tubes. The locking range of the 100-kc multivibrator has been increased by a change in the value of the grid resistors and by increased coupling to the oscillator. The addition of voltage regulation to the oscillator minimizes frequency change when the multivibrators are switched on. The amplitude of the 1-Mc harmonics above 500 Mc has been made more uniform by a different value of the coupling capacitor and the addition of a damping resistor. The price paid for this improvement in the u-h-f range is a decrease in

[1] Robert B. Richmond, "The Unit Crystal Oscillator, A Simplified Frequency Standard for the Small Laboratory", *General Radio Experimenter*, XXVI, 9, February, 1952, pp. 1–4.

Figure 1. View of the Type 1213-AB Unit Crystal Oscillator with the Type 1203-A Unit Power Supply.

output voltage at lower frequencies.

All new orders for the Type 1213-A will receive delivery of the improved Type 1213-AB at no increase in price. For those customers, who already own a Type 1213-A, the improved performance can be obtained by the purchase and installation of a modification kit available for a nominal charge from the Service Department.

Like other General Radio Unit Instruments, the Unit Crystal Oscillator combines small size and low-price with unusually good performance and wide utility. In addition to its many uses as a calibrator and marker generator in the laboratory it can, in conjunction with the Type 1202-A Unit Vibrator Power Supply,[2] be operated from a storage battery for field measurements.

[2] Bousquet, A. G., "The Unit Vibrator Power Supply" *General Radio Experimenter*, XXIX, 9, February, 1955, pp. 6–7

PHASE MONITORING SYSTEM

By S. A. Olson*

An interesting problem of continuously checking the phase of a customer's generating station against the phase of the stand-by power-mains from the Commonwealth Edison Company of Chicago was solved through the use of the phase shifting capabilities of the Variac autotransformer when connected to a three-phase circuit.

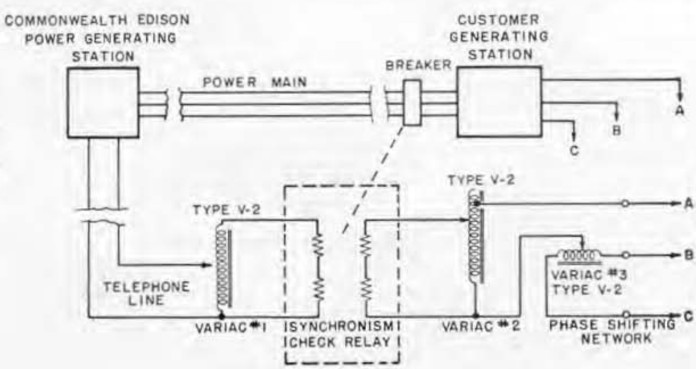
The application is a phase monitoring scheme which automatically opens a customer's generating station bus tie breaker to the Commonwealth Edison Company system when the two systems drop out of phase for any reason.

At the customer's generating station a synchronism-check relay continuously compares the phase angle between the customer's voltage and the Commonwealth Edison voltage. The two voltage sources are approximately ten miles from each other, and their comparison is possible via leased Illinois Bell Telephone Company circuits. If the phase angle between the two systems exceeds approximately five degrees for a short time, the synchronism-check relay will operate to separate the two systems.

All control equipment is owned by the customer.

The circuit, shown below, contains three Type V-2 Variacs and a synchronism-check relay. The distant reference voltage from the Commonwealth

* Planning Engineering, Commonwealth Edison Company



Functional diagram of the circuit used for phase monitoring.

Edison Company is fed into Variac #1. The purpose of this Variac is to compensate for any normal voltage drop in the leased Illinois Bell Telephone Company circuit. Variac #2 is used to boost the voltage from the phase shifting circuit, and Variac #3 is used in the phase shifting portion of the circuit.

Phase angle between the two systems is compared in the synchronism-check relay which opens its contacts to "break parallel" when the two systems differ by a predetermined angle.

The scheme is placed in operation by adjusting the voltage of the leased circuit with Variac #1 and adjusting the phase and voltage of the customer's system with Variacs #2 and #3. Any change in phase occurring after the scheme is in operation causes the relay to operate and opens the customer's paralleling tie breaker between the customer and the utility company. It is then the customer's responsibility to recheck the phase to determine whether the two systems are in phase, prior to reclosing of the tie breaker and paralleling the systems.

CORRECTION—TYPE 1219-A UNIT PULSE AMPLIFIER

In the July issue, the power supply input requirements for this amplifier were given as 102-125 volts, 50 to 60 cycles. The correct statement is 105 to 125 (or 210 to 250) volts, 50 to 60 cycles.

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