B602

UNIVERSAL RF BRIDGE

MAINTENANCE MANUAL

WAYNE KERR

UNIVERSAL RF BRIDGE

B602

MAINTENANCE MANUAL

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The Wayne Kerr Company Limited CHESSINGTON Surrey England

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ILLUSTRATIONS

INTRODUCTION

1. The Operating Instructions supplied with the instrument detail the physical description, specification and use of the bridge, whereas this manual contains all the necessary information for those users who require a detailed knowledge of the circuit used, its operation and adjustment.

The book contains a complete technical description of the instrument and the setting-up procedure necessary to keep the instrument in good order.

Complete instructions are given for the adjustment of all preset controls and for the manufacture of the inductance standards used in the setting-up procedure, together with internal views of the equipment and a circuit diagram.

2. ## TECHNICAL DESCRIPTION

The Universal RF Bridge B602 uses the transformer ratio-arm principle. A complete analysis of this type of bridge is given in the Wayne Kerr Monograph No. 1, 'The Transformer Ratio-Arm Bridge'. An analysis of the self-balancing principles used in this instrument is given in Electronic Engineering Vol. 35, No. 430, December 1963, 'Self-Balancing Transformer Ratio-Arm Bridges'. Copies of the Monograph and reprints of the article are available on request.

The major assemblies in the instrument are the nucleus and pushbutton switch assembly, an inductance standard and two Magpots*. Since the bridge operates at r.f., the voltage and current transformers - there are three of each - are miniature components wound on ferrite cores; they are located in the nucleus unit. The full circuit diagram of the B602 is given in Fig. 8.

The first voltage transformer TE1 serves also to match the bridge input impedance to the external source output. The secondary of TE1 feeds the next voltage transformer TE2 via the phase correcting network

*From 'magnetic potentiometer'

C1/RV2. This network removes an excessive C term that would otherwise be present during G measurements at the lower frequencies.

Transformer TE2 is tapped at 1 turn to feed the middle range of parallel measurements and also the third voltage transformer TE3. The 1 turn tap on TE3 feeds the highest range of parallel admittance measurements. This tap is equivalent to 0.1 turn on transformer TE2; the arrangement is necessary because of the impossibility of producing fractional turns.

Transformers TI1, TI2 and TI3 are the equivalent current transformers. Transformer TI2 is symmetrically wound about neutral to provide the phase reversal necessary for the summing of the unknown and standard currents. Transformers TI3, TE2 and TE3 are physically identical and have a -1 turn tap, i.e. the neutral connection is made at one turn from the end of an eleven turn winding. The -1 turn on TE2 is used as an offset or back winding, in TE3 the -1 turn is not used while in TI3 it is used for sign reversing. Capacitors C4 and C5 are connected to the -1 turn on TE2 so as to offset the capacitance between neutral and ground; this is necessary when 'floating neutral' measurements are made.

The basis of the Magpot is a single loop of 4" diameter, having an inductance of approximately 0.3μH. The loop voltage is reinforced at 90° intervals by means of a four-turn transformer (TE5 or TE7) which effectively reduces the 'take-off' impedance at the Magpot output to approximately $^{1}/8$ of its input impedance (plus lead impedance) at 1MHz.

The voltage from the secondary of TE1 is fed to the L/C Magpot via C2 and the matching transformer TE4, and to the G/R Magpot via C3 and TE6. The capacitors C2 and C3 correct the Magpot voltage output characteristic (which would otherwise rise slightly) at the lower frequencies. The input impedance of the Magpot is approximately 0.2Ω at 100kHz and this is transformed to 80Ω to avoid overloading TE1. Transformers TE4 and TE6 are designed to have minimum capacitive coupling between the windings so that the neutral output connection can be made at any point on the Magpot loop.

By selecting a point at approximately 45° from the input low for the neutral output and, by arranging the scale length (0 - 1) to occupy approximately 270°, a quarter of the scale length is made available for trimming and to provide a small range overlap at both ends of the scale.

Each scale drum is connected to its Magpot by means of a slipping clutch and both scales are simultaneously locked when the cam mechanism (the Scale Lock control) is operated. Thus, with the scales locked at zero, the Magpots can be operated to trim the bridge.

The output from the L/C Magpot feeds the inductance and capacitance standards simultaneously. The required standard is selected by the switch S3, which is so arranged that the unused standard is connected back to its own neutral. In the case of the inductance standard, the return connection is via R6 so as to reduce the loading at 100kHz.

The inductance standard L1 is an air-cored toroid whose external field is so small that the presence of metal objects near the coil has no measurable effect. The trimming components, L2 and C9, are located within the screening can of the standard. Trimmer C9 corrects the performance of the standard at frequencies above 5MHz.

The capacitance standard comprises C6 and the trimmer C7. These components are built in to the nucleus in such a way that their bodies pass through the central neutral screen, thus avoiding direct coupling between the voltage and current arms of the bridge. The L or C sign is selected by switch S4, and the L or C multiplier by switch S5.

The network C10, C11 and L4 corrects the capacitance standard at the higher frequencies. At low frequencies L4 has a low impedance so that C10 and C11 appear only as loads on the voltage and current arms respectively, having little effect on the standard. At the higher frequencies, the impedance of L4 increases and C10/C11 become increasingly effective as a series/parallel combination with the capacitance standard.

When low value capacitors are measured on the parallel bridge, the difference in loading on the unknown and standard arms of the bridge (1pF and 30pF respectively) would become serious at the higher frequencies. To compensate for this, C8 - whose value is made approximately equal to that of the standard - is switched by S3d and S4c to the appropriate anti-phase winding on TI2.

The conductance/resistance standard comprises R1 and the series trimmer RV1, these being fed by the output from the G Magpot. Switch S1 selects the G multiplier and switch S2 selects the G sign.

Since all the switching is arranged on the current arm of the bridge, any inter-switch capacitance contributes only to the loading to neutral on the current transformer and so does not affect the bridge balance.

The low impedance, or series bridge measurements are made by connecting the unknown as the shunt arm of a T-network (see Monograph No. 1). In this instrument, the series arms are built-in as part of the bridge nucleus. Resistors R2 and R4 are the series arms for the lowest impedance range (series bridge) while R3 and R5 are the corresponding components for the highest range.

Resistor R7 across the primary of the bridge output transformer TI1 maintains the output impedance at the higher frequencies. The secondary of TI1 is connected to the bridge output (Detector) via the common mode rejection transformer (or coaxial choke) L3.

3. CHECKING AND SETTING-UP PROCEDURE

The following paragraphs give complete instructions for the adjustment of all the preset controls in the instrument. Where appropriate, tests are given to show up any departure from the original condition. The sequence of the tests and adjustments is not important but is arranged for minimum alteration of connections. A general view of the instrument is given in Fig. 9, while detailed views of the nucleus assembly are given in Fig. 10.

3.1 TEST EQUIPMENT REQUIRED

The following items of test equipment are required to facilitate the checking and setting-up of the instrument.

(i)	Source and Detector	Wayne Kerr Type SR268
(ii)	Coaxial Adaptor	Wayne Kerr Type C602
(iii)	Universal Bridge (0.1%) e.g.	Wayne Kerr Type B641, B642 or B224

(iv) The following capacitance and conductance standards, which should be either set to their correct value (±0.1%) or measured on the bridge (item iii).

Capacitance Standards:	1.0pF*; 10.0pF*, 100.0pF*; 1nF§; 10nF§.
Conductance Standards:	10.0μ℧ (100kΩ)†; 100μ℧ (10kΩ)*; 1.0m℧ (1kΩ)*; 10.0m℧ (100Ω)†; 100m℧ (10Ω)†.
Inductance Standards	1μH and 10μH (see Appendix for details)
Resistance Standard:	100 + 100Ω centre-tapped. Use two resistors, nominally 100Ω, matched to within 0.2%.

Note 1: The Standards marked * are available in the Wayne Kerr series Q201; their use is recommended for setting-up the B602 because they are specially constructed to remain constant with frequency. It is essential that the conductance standards used (except the 10μ℧) should have minimum series inductance; the 10μ℧ standard must have minimum shunt capacitance. If standards having other than BNC connectors are used, the Coaxial Adaptor C602 is not required.

The neutral screen, ground strap and miniature probe connector, mentioned in certain operations, are part of the normal B602 equipment.

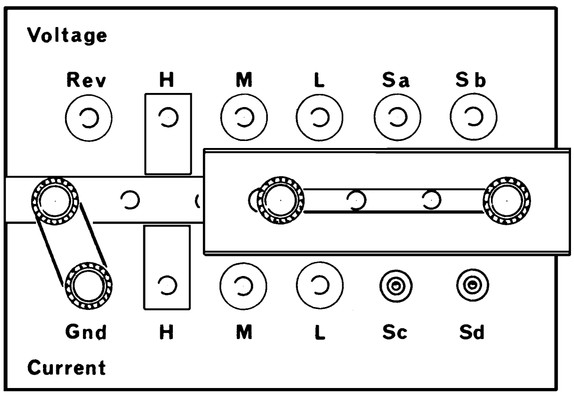
Note 2: For the Standards shown thus †, close tolerance unscreened metal film resistors may be used connected directly to the bridge. The 10μ℧ standard must have low shunt capacitance and the 10m℧ and 100m℧ standards must have low series inductance.

Note 3: Close tolerance silver mica capacitors, having low series inductance, may be used for the standards shown thus §.

3.2 TRIM AND ZERO CHECKS

(i) Connect the B602 to the Source and Detector. Connect the ground strap and the neutral screen as shown in Fig. 1. Press all five buttons in the top row of the switch bank. Set the source frequency to 1MHz. Carefully trim the bridge (see Operating Instructions; Initial Trimming - Parallel Measurements). When the Scale Lock Control has been released, check trim and absence of discernible backlash by approaching balance from both sides of zero.

Fig. 1



(ii) Press the G/R '-' button and rebalance the bridge; note the deviation from zero for both scales. Press the G/R '+' and C/L '-' buttons, rebalance the bridge and again note the deviation from zero for both scales. Finally, press the G/R '-' button and repeat the process. In each case, the deviation from zero should not be greater than ±1 small division. Press both '+' buttons.

(iii) Repeat (ii) but with the $L_p C_s$ button pressed.

(iv) Press the $C_p L_s$ button, set the source frequency to 100kHz, balance the bridge and note the deviation from zero on both scales as before. Repeat this test with the $L_p C_s$ button pressed. In both cases, the deviation from zero should not be greater than ±3 small divisions. Press both the '+' buttons.

(v) Repeat (iv) but with a source frequency of 5MHz. The same tolerance applies.

(vi) Repeat (iv) but with a source frequency of 10MHz. The deviation from zero should not be greater than ±5 small divisions.

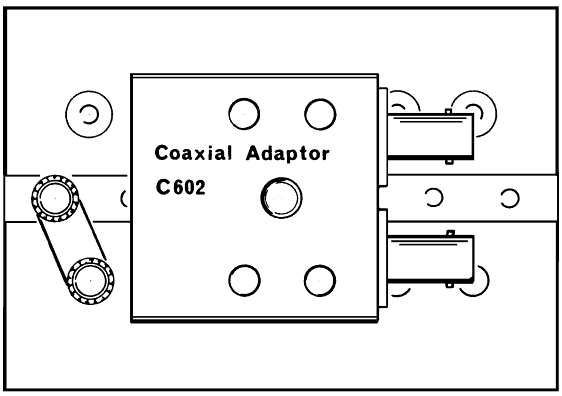
3.3 REMOVAL OF CASE

Before any adjustments can be made, the instrument case must be removed as follows. The case is in two parts, the major part being secured by means of four quick-release fasteners at the rear of the instrument. When this is removed, the rear cross rail, at the top, can be slid backwards until it is free from the terminal panel surround. Remove the cross rail and lift away the terminal panel surround.

3.4 ADJUSTMENT OF THE CONDUCTANCE STANDARD

Connect the Coaxial Adaptor (Section 3.1 (ii)) as shown in Fig. 2. Set the source frequency to 1MHz and carefully trim the bridge. Connect the 1m℧ standard to the coaxial adaptor and balance the bridge. Set the G/R scale to the true value of the standard and restore balance by adjusting RV1.

Fig.2



Remove the 1m℧ standard, set the source frequency to 100kHz and carefully check the bridge trim. Reconnect the 1m℧ standard and balance the bridge. Set the C scale to 0 and restore balance (or as nearly as possible on the positive side of zero) by adjusting RV2.

Measure the 1m℧ standard at the frequencies given in the following table. Check the trim at each frequency (with the standard temporarily removed) before making the measurement. The value at each frequency, with respect to the value at 1MHz, should be within the stated limits.

Frequency	Allowable Tolerance
100kHz	±0.7% (7µ℧)
1MHz	True value of standard
3MHz	±0.7% (7µ℧)
5MHz	±1.5% (15µ℧)
10MHz	±4.0% (40µ℧)

Note: In this test, the minor term may increase slightly at the lower frequencies. This can be ignored.

3.5 ADJUSTMENT OF THE CAPACITANCE STANDARD

Set the source frequency to 1MHz. Remove the neutral screen and connect the Coaxial Adaptor to the terminal block as shown in Fig. 2. Trim the bridge. Connect the 10pF standard to the Adaptor and balance the bridge. Set the C scale to the true value of the standard and restore balance by adjusting trimmer C7.

Measure the 10pF standard at the frequencies given in the following table. Check the trim at each frequency (with the standard temporarily removed) before making the measurement. The value at each frequency with respect to the value at 1MHz, should be within the stated limits.

Frequency	Allowable Tolerance
100kHz	±0.7% (0.07pF)
1MHz	True value
3MHz	±0.7% (0.07pF)
5MHz	±1.5% (0.15pF)
7MHz	±3.0% (0.3pF)
8MHz	±3.0% (0.3pF)
9MHz	±4.0% (0.4pF)
10MHz	±4.0% (0.4pF)

In this test, the minor term may increase slightly at the higher frequencies. This can be ignored.

If, in the previous paragraph, the measurements between 5 and 10MHz are outside the specified tolerance, adjust the trimmer capacitor C10 and repeat the measurements until the specified tolerance is met.

Note: The components used as standards on this bridge must be pure, i.e. resistors of metal film type having low series inductance especially on low resistance values, and capacitors of silver mica type having low series inductance especially on high values.

3.6 RANGE TO RANGE CHECK

Set the source frequency to 300kHz. Measure the following standards, having first checked their value at 1kHz or 1592Hz on the bridge quoted in Section 3.1 (iii). In each case, the value as measured on the B602 should be within 1% of the value measured at a.f.

Standard	B602 Range	Terminals Used (Fig. 1) Voltage	Current
1m℧	6	M	M
100pF	6	M	M
100μ℧	7	M	L
10pF	7	M	L
1pF	8	L	L

At each change in the terminal arrangement in the coaxial adaptor, check the bridge trim before proceeding with the measurement. Remove the coaxial adaptor and the ground strap.

Using the a.f. bridge (Section 3.1 (iii)), check the value of the standards listed in the following table. Connect the standards, in the order given, and the neutral screen as shown in Fig. 3 and 4. In each case, before making the measurement, disconnect the voltage side of the standard (rear terminal), check the bridge trim and then reconnect the standard to the appropriate voltage terminal. The value measured on the B602 should be within 1% of the value as measured on the a.f. bridge.

Standard	B602 Range	Terminals Used Voltage	Current	
10μ℧	8	L	L	
10m℧	5	H	M	see Fig. 3
1nF	5	H	M	see Fig. 3
100m℧	4	H	H	see Fig. 4
10nF	4	H	H	see Fig. 4

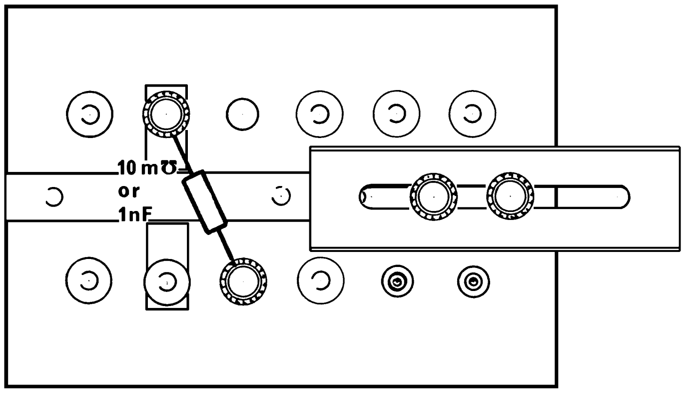


Fig. 3

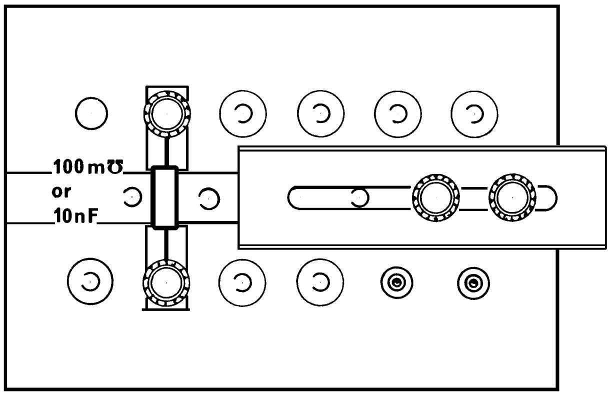


Fig. 4

3.7 ADJUSTMENT OF THE INDUCTANCE STANDARD

This adjustment procedure should not be attempted unless high quality inductors are available. Details are given in the Appendix for the manufacture of the 1μH and 10μH standards. Where it is considered impractical to make these components, high quality inductors measured against a sub-standard must be used.

(i) Mount the 10μH standard and the neutral screen as shown in Fig. 5. Set the source frequency to 200kHz. Press the L_pC_s button. With the voltage terminal connected to neutral, carefully trim the bridge. Transfer the voltage screw to 'H' and balance the bridge. Set the L scale to the true value of the 10μH standard (at 200kHz) and rebalance the bridge by adjustment of L2. If necessary, a small adjustment to the G scale can be made.

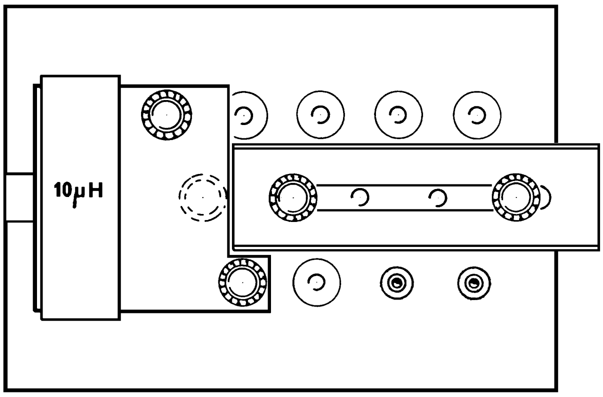


Fig.5

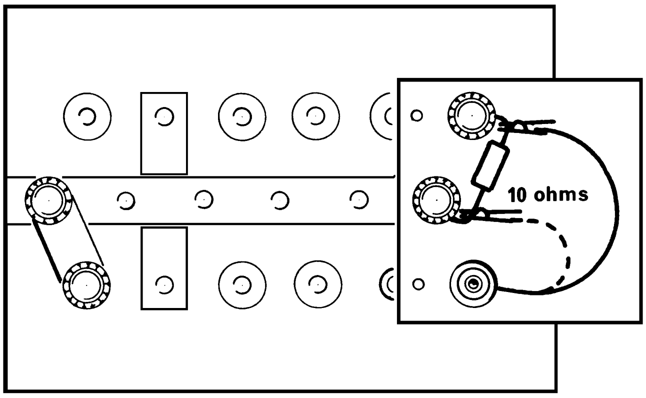
(ii) Set the source frequency to 100kHz. Transfer the voltage screw to neutral (Fig. 5) and check the bridge trim. Connect the voltage screw to 'H' and balance the bridge. The measured value at 100kHz should be within ±0.7% of the true value of the standard at that frequency (see Appendix); if it is not, make a small adjustment to L2 such that the measured value comes within the allowed tolerance. If this second adjustment to L2 is made, it will be necessary to check that the value as measured at 200kHz is still within tolerance (check the bridge trim as before).

(iii) Connect the 1μH standard to Range 4 (H terminals). Measure and record the value at the following frequencies: 300kHz, 1, 3, 5, 7 and 10MHz. At each change of frequency, move the voltage 'H' screw to neutral, check the bridge trim and then return the screw to the 'H' terminal for the measurement. If the values measured between 5 and 10MHz differ from the true value of the standard at the same frequency by more than ±5%, adjust the trimmer C9 to bring the values within tolerance. (Screw C9 in to reduce the measured value of the standard, and vice versa). If the setting of C9 is changed, repeat (ii) and (iii). Remove the standard and press the C_pL_s button.

3.8 SERIES BRIDGE CHECK

Remove the neutral screen and connect the standardized 10Ω (100m℧) resistor as shown in Fig. 6. Set the source frequency to 1MHz. Insert the miniature probe connector into the front right-hand socket and connect the clip to the component lead connected to the neutral bar as close to the body of the component as possible. Transfer the miniature crocodile clip to the other side of the resistor close to the component body and balance the bridge. The bridge indication should be within the

Fig.6

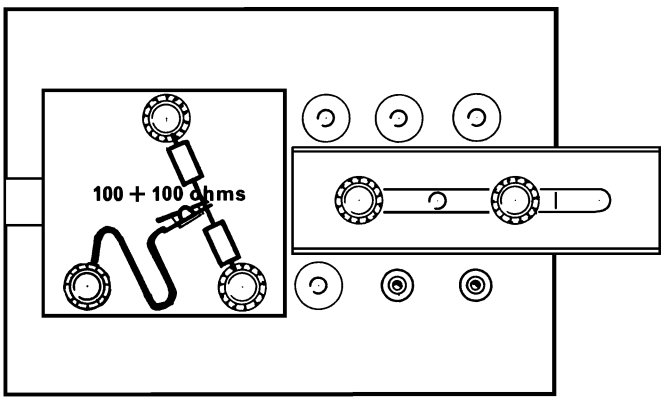


limits +0 to -4% of the value of the standard as measured on the a.f. bridge (Section 3.1 (iii)). Note that this tolerance includes a systematic error of -2%. Remove the standard.

3.9 BALANCE CORRECTION

Remove the ground strap and connect the neutral screen as shown in Fig. 7. Check the bridge trim. Connect the 100 + 100Ω standard as shown (Fig. 7) but leave the centre-tap unconnected. Balance the bridge and note the indicated R value. Connect the centre-tap to the ground terminal and rebalance the bridge. If the indicated R value changes, adjust the trimmer C5 until the two R indications are the same (i.e. no change when centre-tap is grounded or not grounded.) During this procedure, adjust the C scale as required to obtain balance.

Fig.7



Measure the standard, with the centre-tap free and grounded, first at 1MHz and then at 3MHz. In both cases, the change in R value when the centre-tap is grounded should not exceed 1%. Disconnect the standard.

R	RV2 R3 RV1 R2 R1 R4 R5 R6 R7
C	C2 C3 C1 C4 C5 C9 C10 C7 C6 C11 C8
M	SK1 TE1 TE4 TE6 TE5 TE7 TE2 TE3 L1 L4 SK2 SK3 TI3 SB L2 SC TI2 SA SD TI1 SE L3 SK4

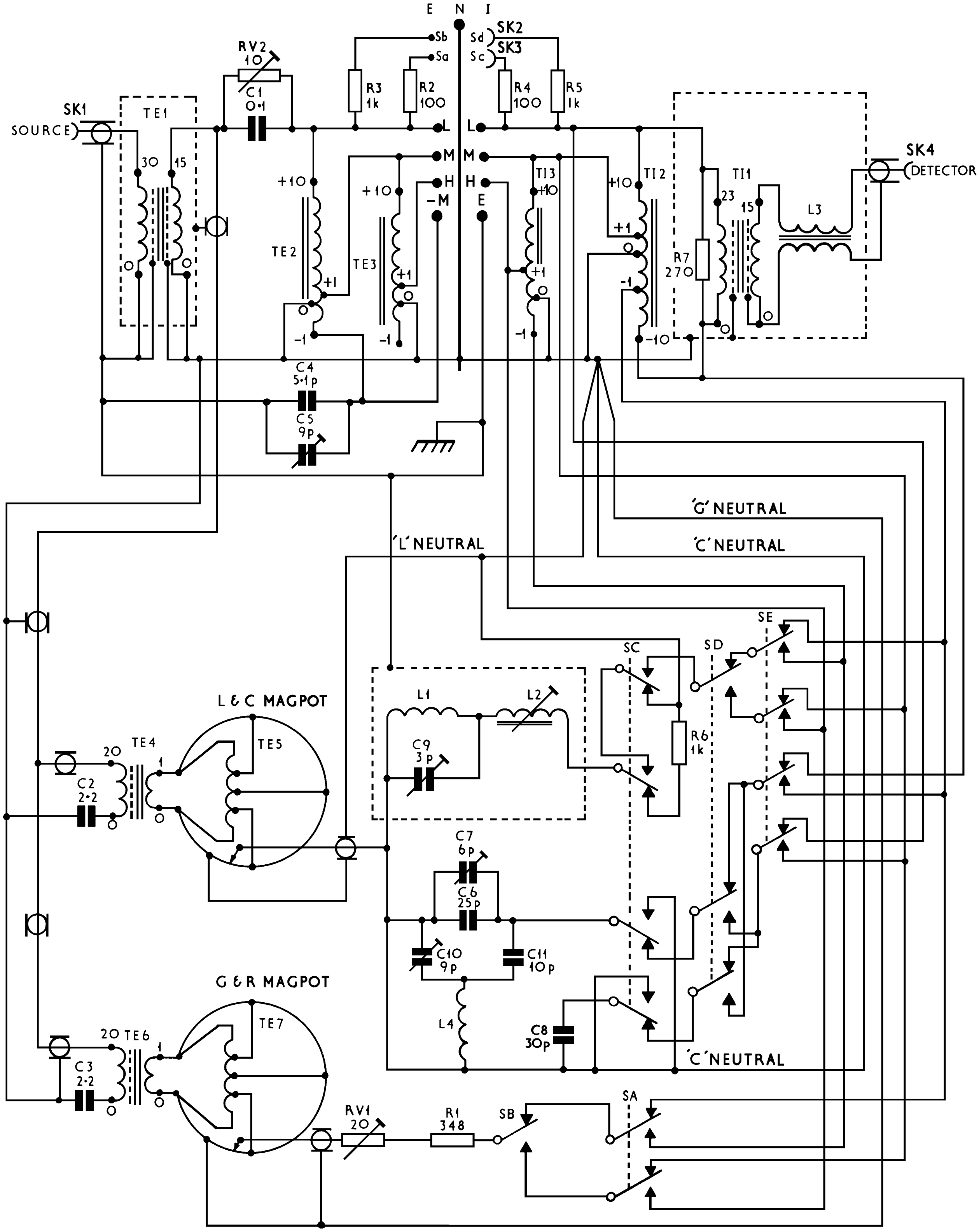


Fig.8 B602 Circuit Diagram Drg.No.D15808 C

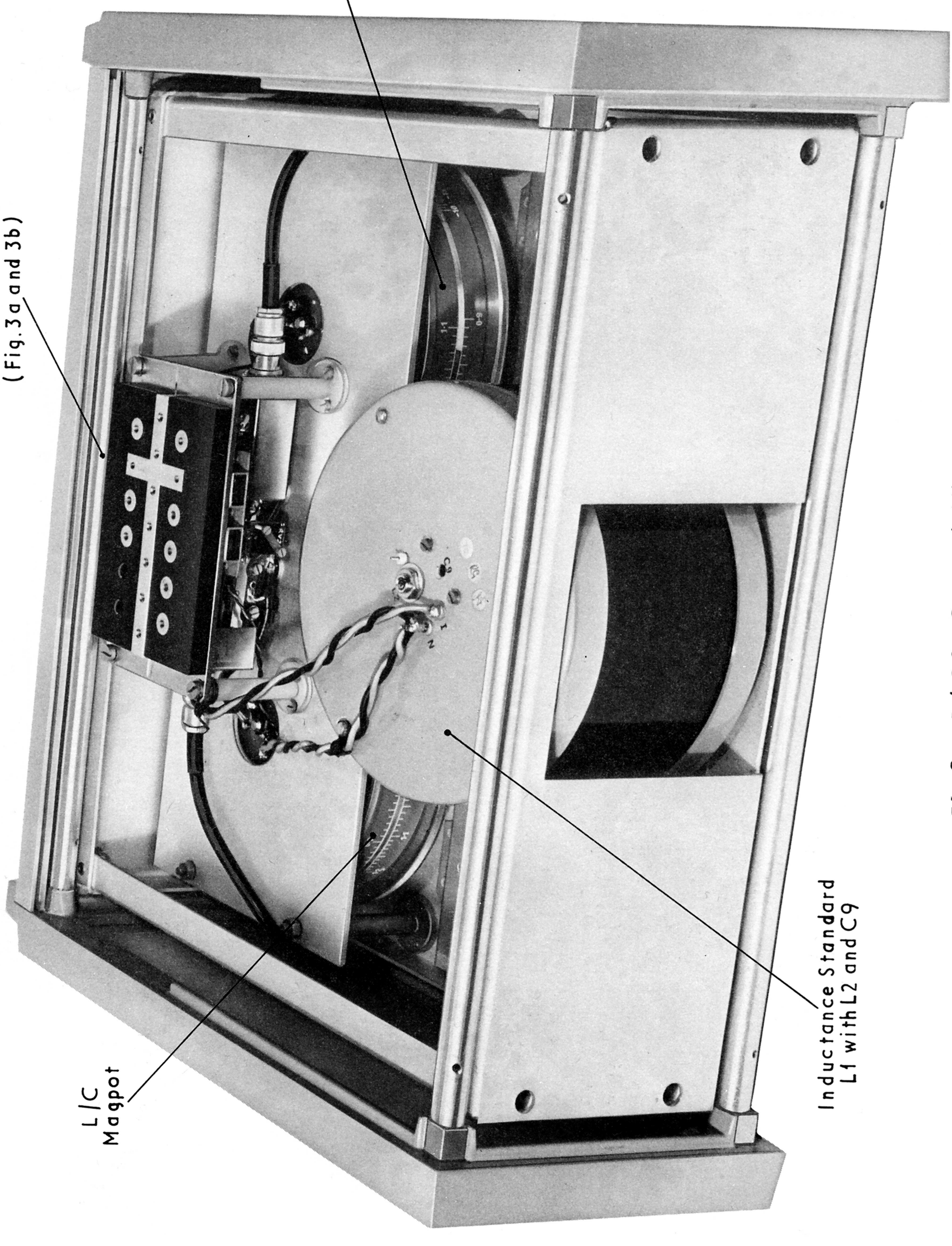


Fig.9 B602: General View

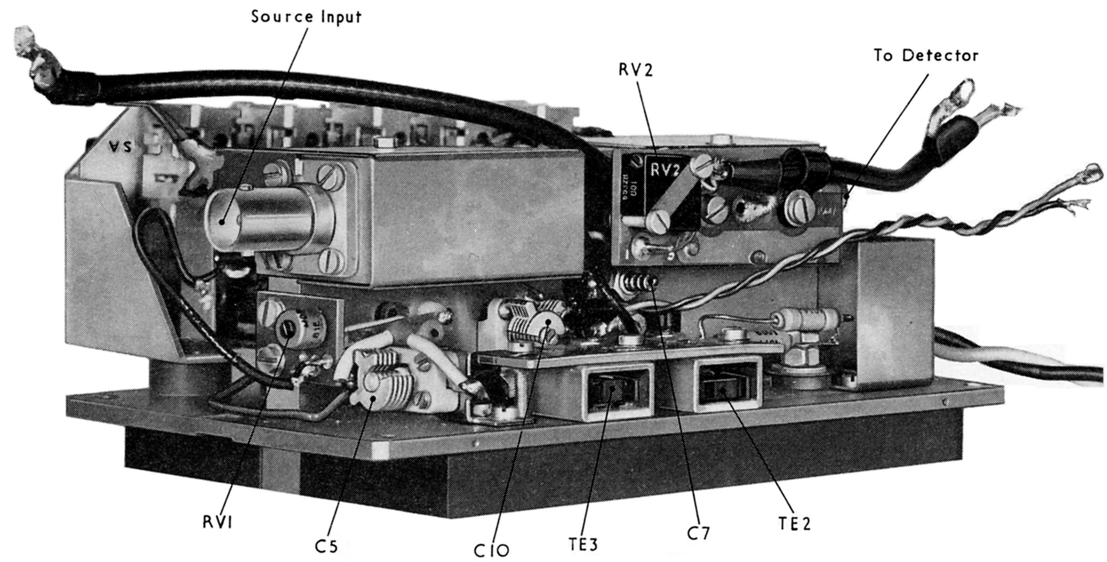


Fig.10a Nucleus & Switch Assembly – Rear View

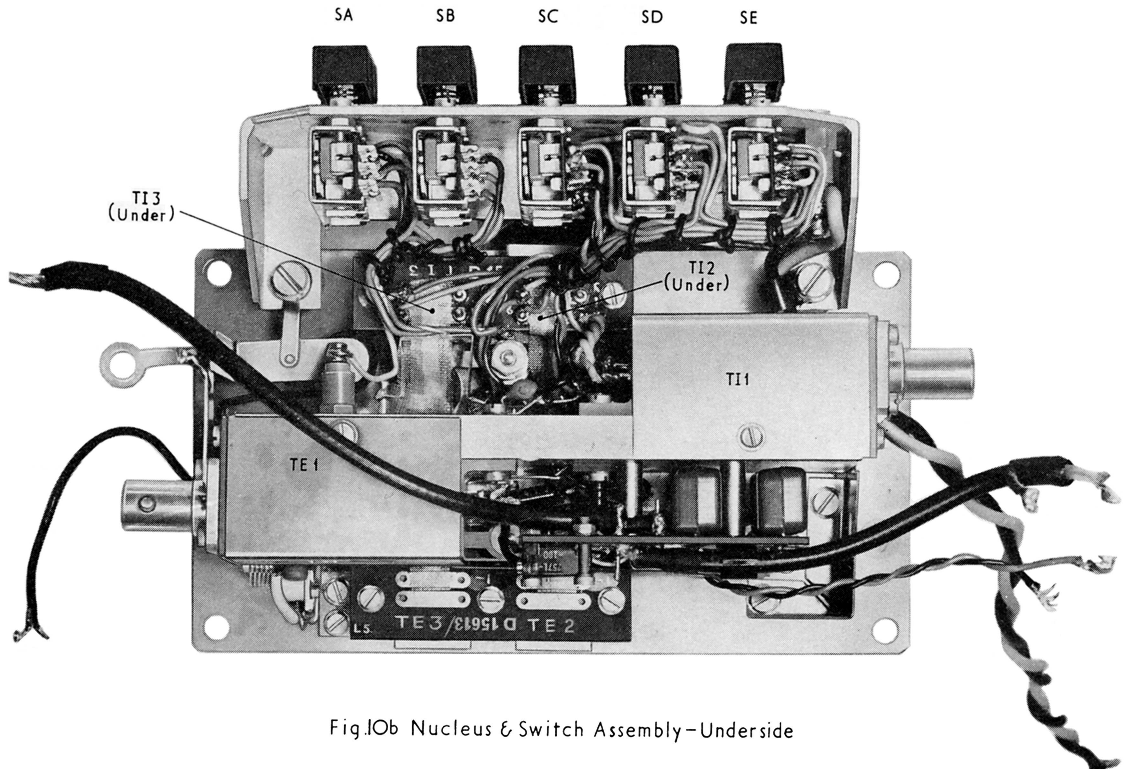


Fig.10b Nucleus & Switch Assembly – Underside

LIST OF COMPONENTS

When ordering components, please state the instrument Model No., Serial No., and Component Reference.

Resistors

Ref	Component	Rating	Man^{ftr} & Part No.
R1	348R 0.5% 100 ppm	$^1/4$W	Morganite Filmet FC65
R2	100R 0.2% 50 ppm	$^1/4$W	Welwyn Welmet 4014
R3	1k 0.2% 50 ppm	$^1/4$W	Welwyn Welmet 4014
R4	100R 0.2% 50 ppm	$^1/4$W	Welwyn Welmet 4014
R5	1k 0.2% 50 ppm	$^1/4$W	Welwyn Welmet 4014
R6	1k 10%	$^1/8$W	Morganite Type X
R7	270R 10%	$^1/8$W	Morganite Type X
RV1	20R 30%	$^1/2$W	Morganite Cermet 81E
RV2	10R 20%		Bourns 3257 L-1-100

Capacitors

Ref	Component	Rating	Man^{ftr} & Part No.
C1	0.1μ 20%	250V d.c.	Mullard C280AE/P100K
C2	2.2μ 10%	63V d.c.	Wima MKS
C3	2.2μ 10%	63V d.c.	Wima MKS
C4	5.1p 5%	750V d.c.	Erie N750 AD
C5	9p -0% +20%	500V d.c.	Wingrove & Rogers C32-01
C6	25p ±1p	350V d.c.	Johnson & Matthey A-12-E
C7	6p <50fF	400V d.c.	Mullard C004/EA/6E
C8	30p 10%	750V d.c.	Erie N750A
C9	3p <50fF	350V d.c.	Mullard C004/EA/6E
C10	9p -0% +20%	500V d.c.	Wingrove & Rogers C32-01
C11	10p 10%	750V d.c.	Erie N750-AD

Transformers

TE1	Manufactured to Wayne Kerr Drawing No. D15720A
TI1	" " " " " " D15720B
TE2	" " " " " " D15717
TI2	" " " " " " D157119
TE3	" " " " " " D15717
TI3	" " " " " " D15717
TE4	" " " " " " D15794/1
TE5	" " " " " " D15794/2
TE6	" " " " " " D15794/1
TE7	" " " " " " D15794/2

Inductors

L1	Manufactured to Wayne Kerr Drawing No. D15789
L2	" " " " " " D15788
L3	" " " " " " D15733
L4	3.3μH 10% Painton type 200208

APPENDIX

Construction of 1μH and 10μH Standards for B602

These inductance standards are wound toroidally to obtain the minimum external field. In each case, the former should be machined from a stable plastic such as Nylon. After winding and before mounting the coils, protect them with a layer of polythene or p. t. f. e. adhesive tape. The copper contacts shown in Figs. A & B should be fixed to the base plate with Araldite and the coils should be mounted as shown in the detail drawing Fig. A. The values of the standards should be measured and recorded at the following frequencies.

STANDARD	MEASUREMENT FREQUENCY IN MHz
1μH	0.01, 0.1, 0.3, 0.5, 1.0, 1.592, 2.0, 3.0, 5.0, 7.0, 10.0
10μH	0.01, 0.1, 0.2, 0.3, 0.5, 1.0, 1.592

Measure the frequency of resonance of both coils, and from this calculate the effective shunt capacitance

$$\text{where } C = \frac{L}{R^2 + (2\pi f L)^2}$$

Details for 1μH Standard

Using the toroidal former detailed in Fig. A, wind 19 turns of silver tape of 0.2 inch width and 0.002 inch thickness, uniformly round the whole circumference. Ensure that the lead-out wires are of sufficient length to make connection to the copper contacts and then wind on polystyrene or p. t. f. e. tape to cover the complete coil.

Details for 10μH Standard

On the toroidal former detailed in Fig. B, wind 70 turns of 100/0.0016 Type 'F' enamel S. S. C. copper wire uniformly over the whole circumference. After ensuring that the lead-out wires are of sufficient length, wind the complete coil in polystyrene or p. t. f. e. tape.

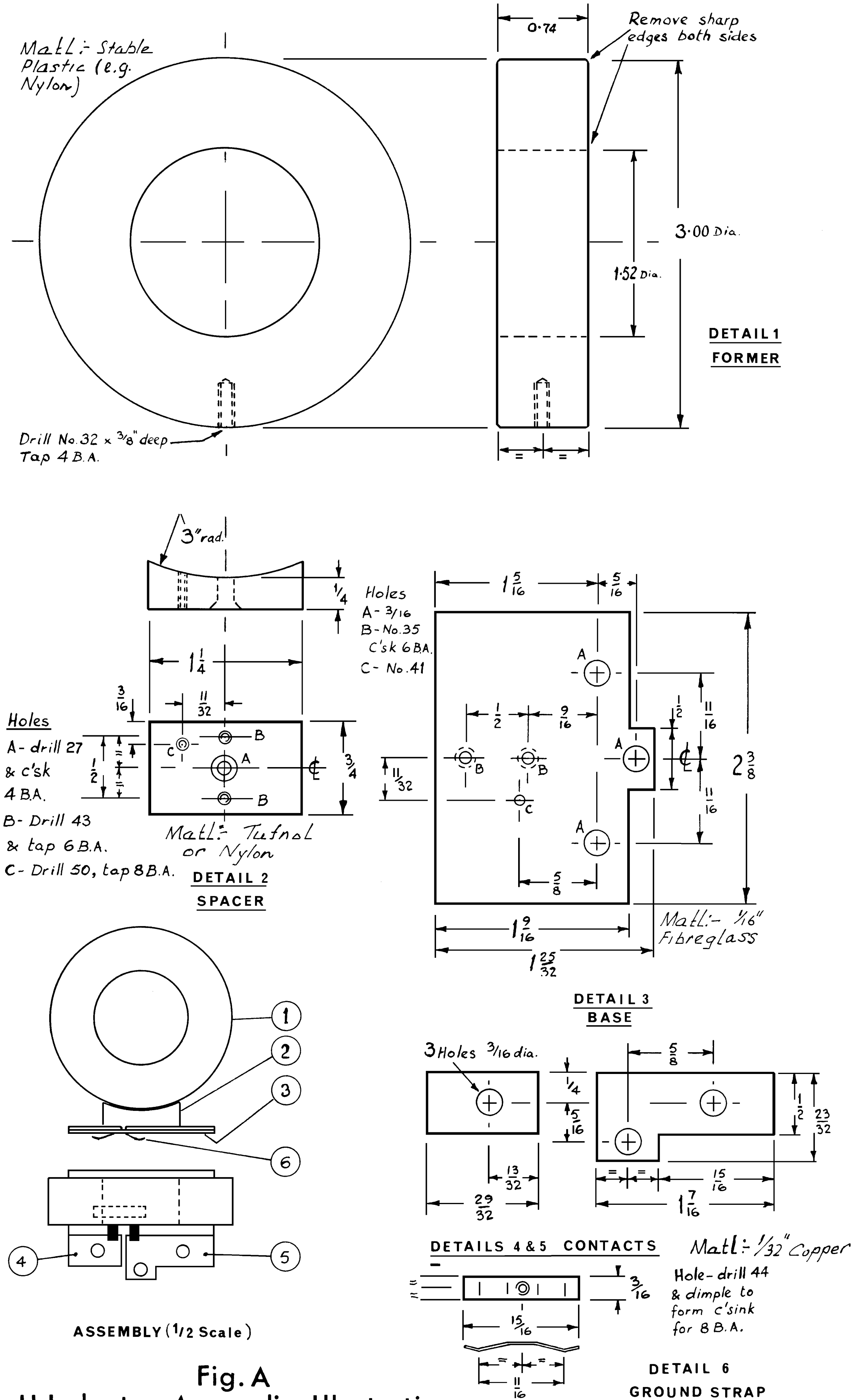


Fig. A
1μH Inductor: Appendix Illustration

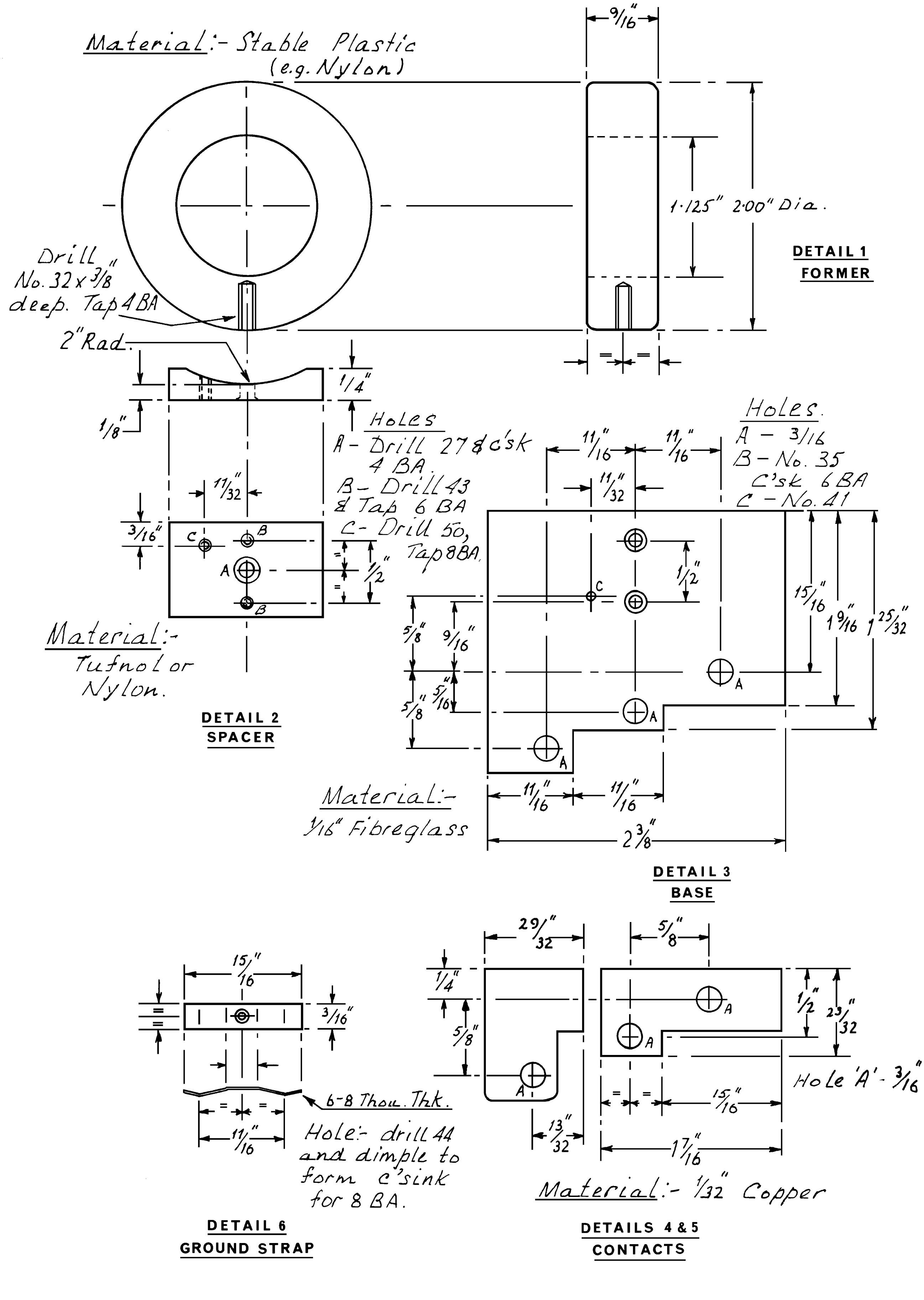


Fig. B
10μH Inductor: Appendix Illustration

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