Keysight 16454A Magnetic Material Test Fixture

Operation and
Service Manual

KEYSIGHT
TECHNOLOGIES

Notices

Trademark Acknowledgments

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CAUTION

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WARNING

A **WARNING** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Table of Contents

1 General Information

Introduction

This manual contains the following information:

- The specifications of the 16454A (in this chapter).
- Initial inspection of the 16454A (see Chapter 2).
- Ordering replaceable parts for the 16454A (see Chapter 5). For measurement procedures using the 16454A, see the applicable impedance analyzer manual/help.

Product Description

The 16454A is used to measure the permeability of a toroidal core.

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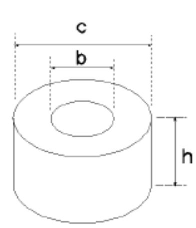
Specifications

This section lists the complete 16454A specifications.These specifications are the performance standards and limits against which the 16454A is tested. When shipped from the factory, the 16454A meets the following listed specifications.

Supplemental characteristics are intended to provide information that is useful in applying the instrument by giving non warranted performance parameters. These are denoted as typical, typically, nominal or approximate.

Applicable MUT (Material Under Test) Size	See Table 1-1
Maximum DC Bias Current	±500mA
Frequency Range	1kHz to 1.0GHz typically
Operating Temperature	-55°C to +200°C
Operating Humidity (@wet bulb temperature <40°C)	Up to 95% RH
Non-operating Temperature	-55°C to +200°C
Non-operating Humidity (@wet bulb temperature <65°C)	Up to 90% RH
Weight	
(Large Test Fixture)	140g typically
(Small Test Fixture)	120g typically
Dimension	
(Large Test Fixture)	ϕ30mm x 35mm H typically
(Small Test Fixture)	ϕ24mm x 30mm H typically

Table 1-1 Applicable MUT Size



Fixture	Small		Large	
Holder	A	B	C	D
b	≥ϕ3.1mm	≥ϕ3.1mm	≥ϕ6mm	≥ϕ5mm
c	≤ ϕ8mm	≤ ϕ6mm	≤ ϕ20mm	≤ ϕ20mm
h	≤ 3mm	≤ 3mm	≤ 8.5mm	≤ 8.5mm

Applicable Instruments

E4990A + 42942A (Option E4990A-120 is required)

E4991B with Option E4991B-002

Supplemental Performance Characteristics

This section shows supplemental performance characteristics data. This supplemental performance characteristics is not specification.

Typical Measurement Accuracy

μ'_r Accuracy $\left(\frac{\Delta\mu'_{rm}}{\mu'_{rm}}\right)$

@ tan **δ** < 0.1

f < 1MHz.. $4 + \frac{25}{F\mu'_{rm}} + \left(\frac{0.1}{F\mu'_{rm}\, f}\right)$ [%] Typical

f ≥ 1MHz................................. $4 + \frac{25}{F\mu'_{rm}} + F\mu'_{rm}\left(1 + \frac{15}{F\mu'_{rm}}\right)^2 f^2$ [%] Typical

Loss Tangent Accuracy of $\dot{\mu}_r(\Delta\tan\delta)$

@ tan **δ** < 0.1... $E_a + E_b$ (Typical)

f < 1MHz

.... $E_a = 0.002 + \frac{0.001}{F\mu'_{rm}\, f}$ (Typical)

.... $E_b = \frac{\Delta\mu'_{rm}}{\mu'_{rm}} \frac{\tan\delta}{100}$ (Typical)

f ≥ 1MHz

.... $E_a = 0.002 + \frac{0.001}{F\mu'_{rm}\, f} + 0.004f$ (Typical)

.... $E_b = \frac{\Delta\mu'_{rm}}{\mu'_{rm}} \frac{\tan\delta}{100}$ (Typical)

Where,

f	is measurement frequency [GHz]
F	$= h \ln \frac{c}{b}$ [mm]
h	is the height of MUT [mm]
b	is the inner diameter of MUT
c	is the outer diameter of MUT
tan δ	is the measured value of loss tangent
μ_{rm}'	is the measured value of permeability

Conditions of accuracy characteristics
• Use the Low Z Test Head for permeability measurement • OPEN/SHORT/50Ω calibration must be done. Calibration ON. • Averaging (on point) factor is larger than 32 at which calibration is done if Cal points is set to USER DEF. • Measurement points are same as the calibration points if Cal point is set to USER DEF. • Environment temperature is within ±5°C of temperature at which calibration is done, and within 13°C to 33°C. Beyond this environmental temperature condition, accuracy is twice as bad as specified.

Figure 1-1 Typical Permeability Measurement Accuracy (@F[1]=0.5)

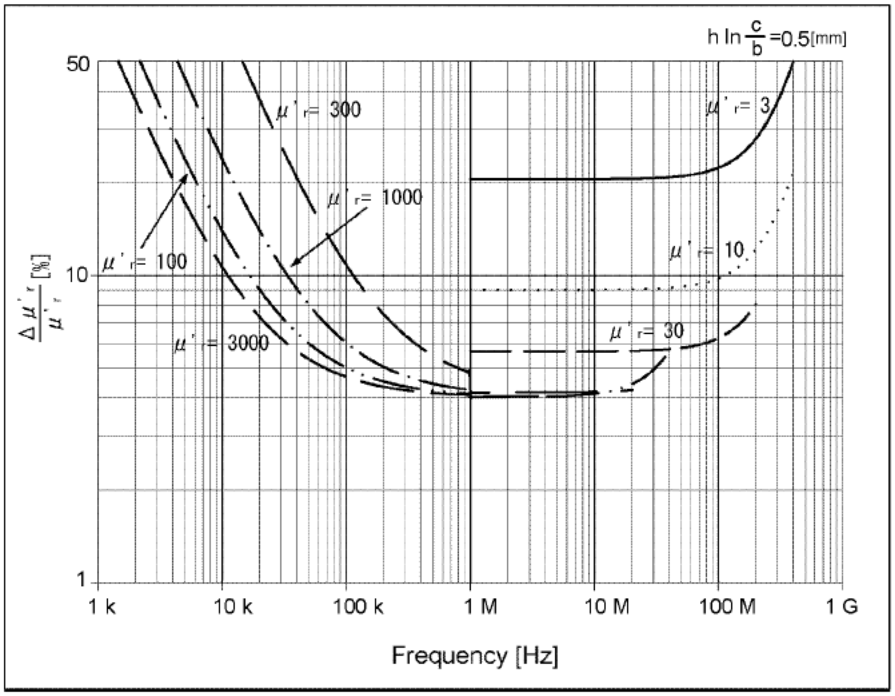
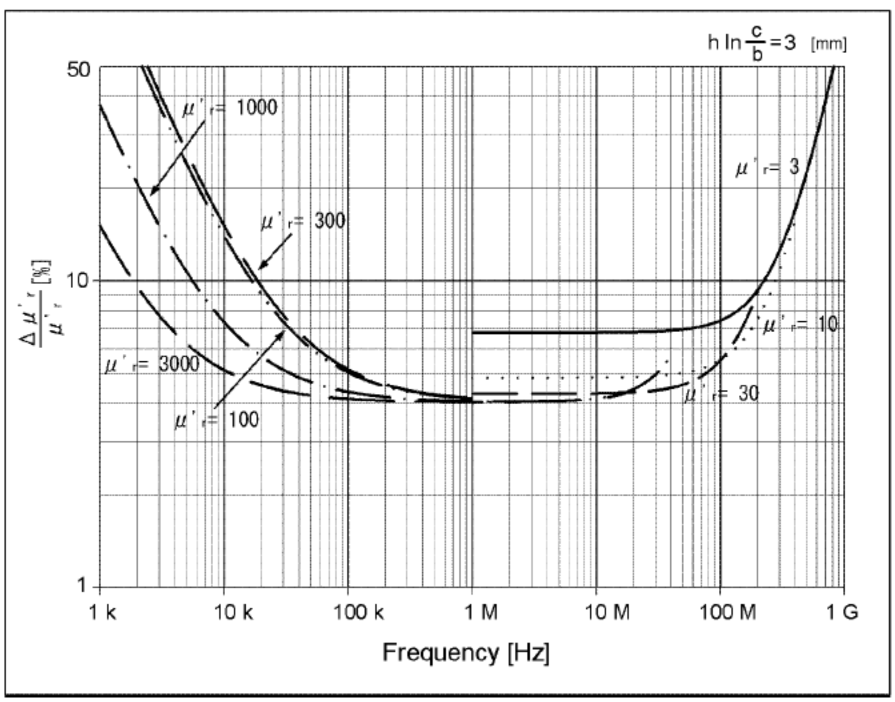


Figure 1-2 Typical Permeability Measurement Accuracy (@F[1]=3)



1. $F = h \ln \frac{c}{b}$

Figure 1-3 Typical Permeability Measurement Accuracy (@F[1]=10)

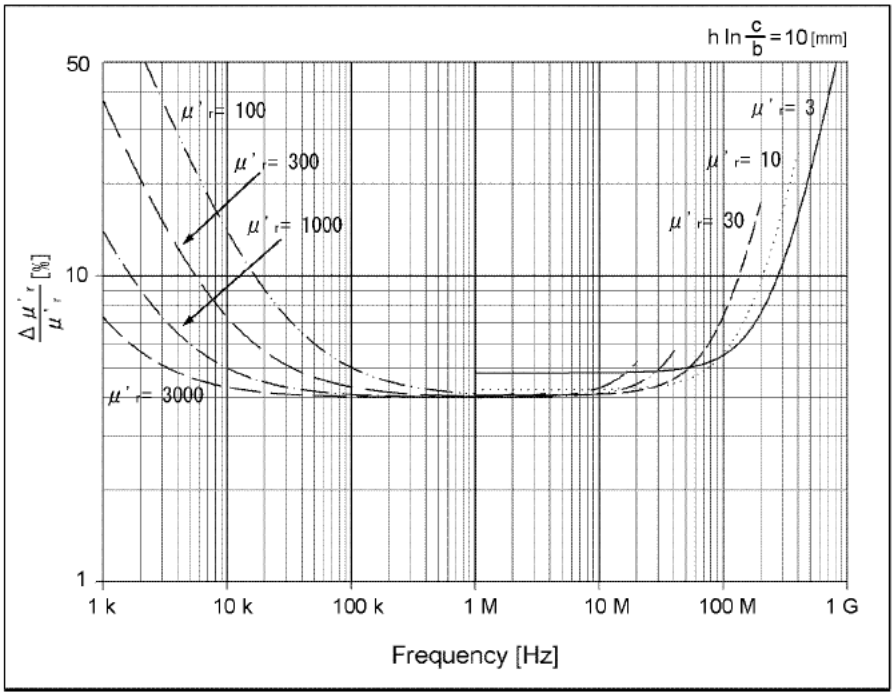
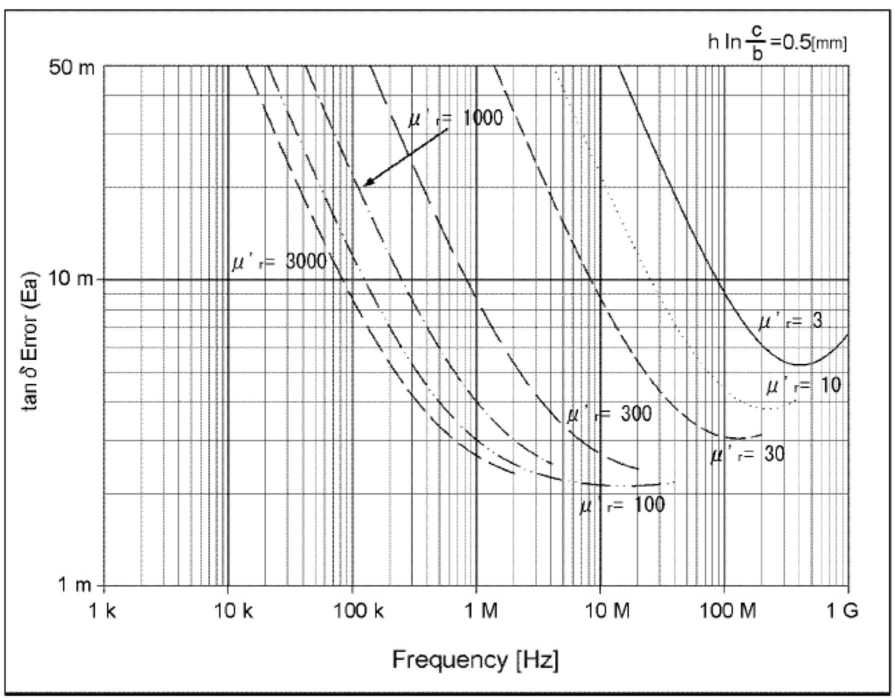


Figure 1-4 Typical Permeability Loss Tangent (tan δ) Measurement Accuracy (@F[1]=0.5)



1. $F = h \ln\frac{c}{b}$

Figure 1-5 Typical Permeability Loss Tangent (tan δ) Measurement Accuracy (@F[1]=3)

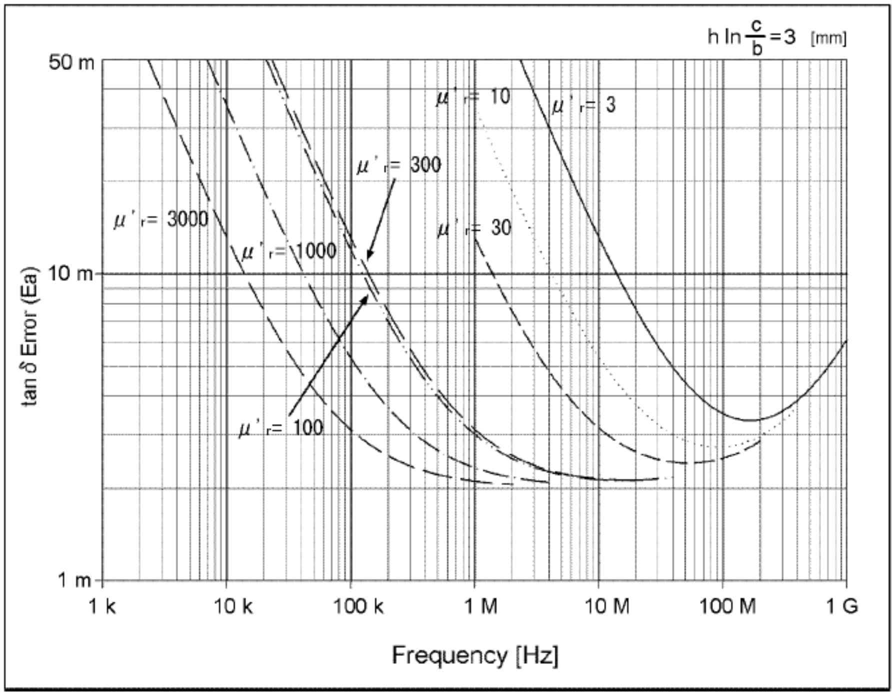
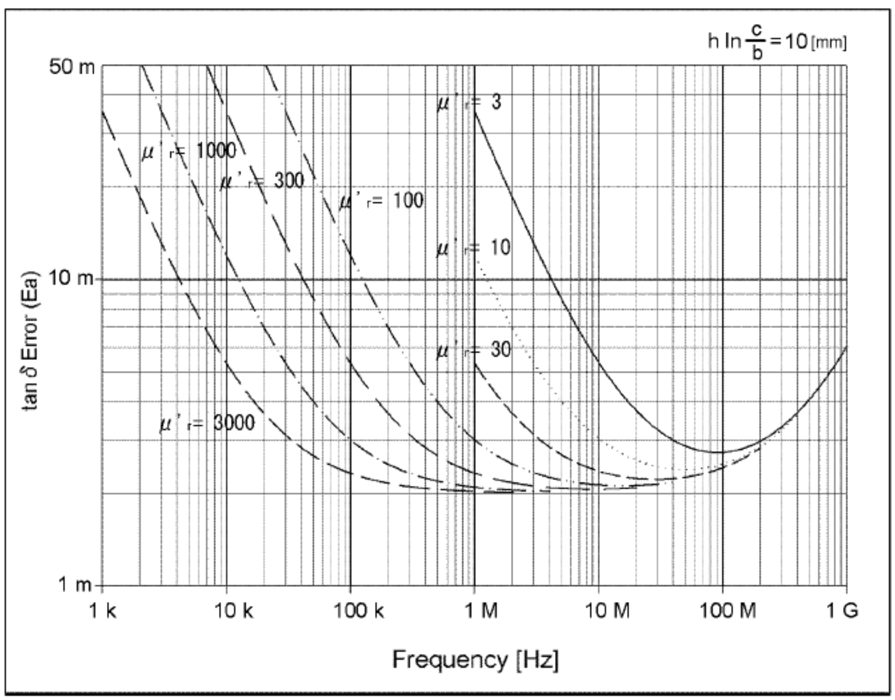


Figure 1-6 Typical Permeability Loss Tangent (tan δ) Measurement Accuracy (@F[1]=10)



1. $F = h \ln\frac{c}{b}$

Figure 1-7 Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @F[1]=0.5)

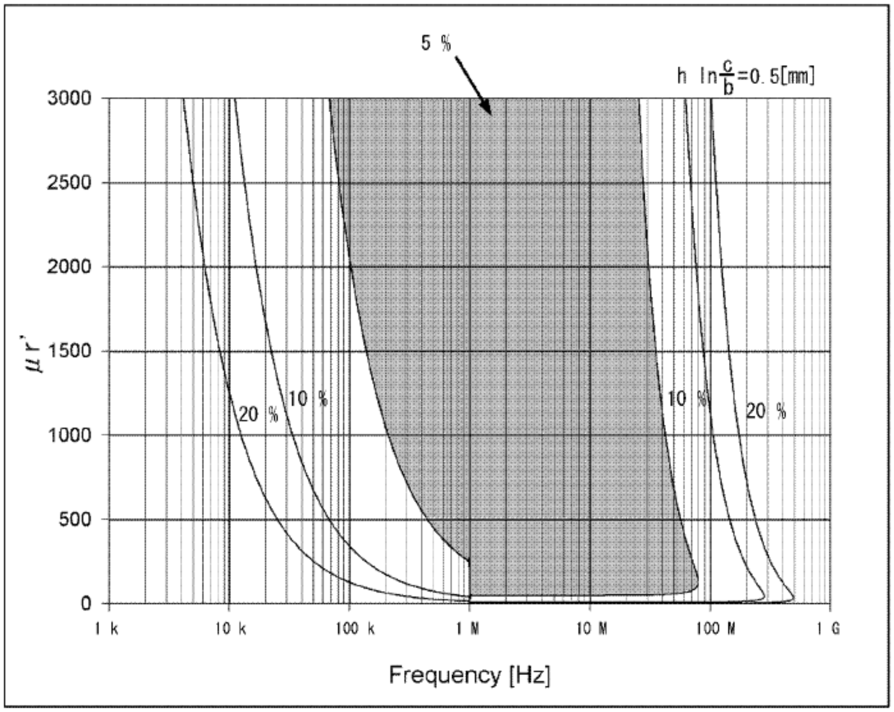
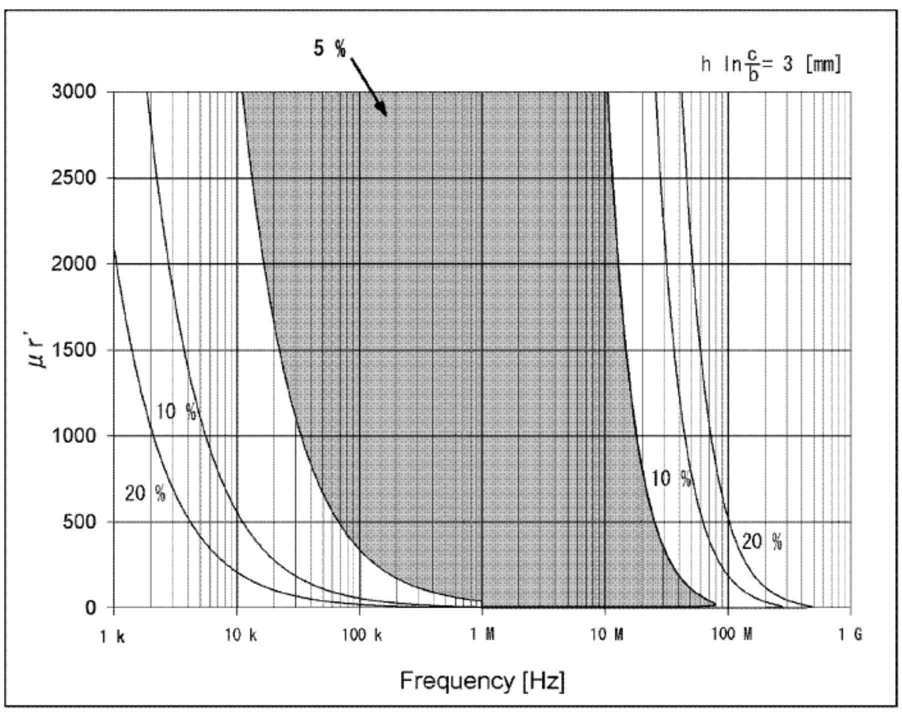
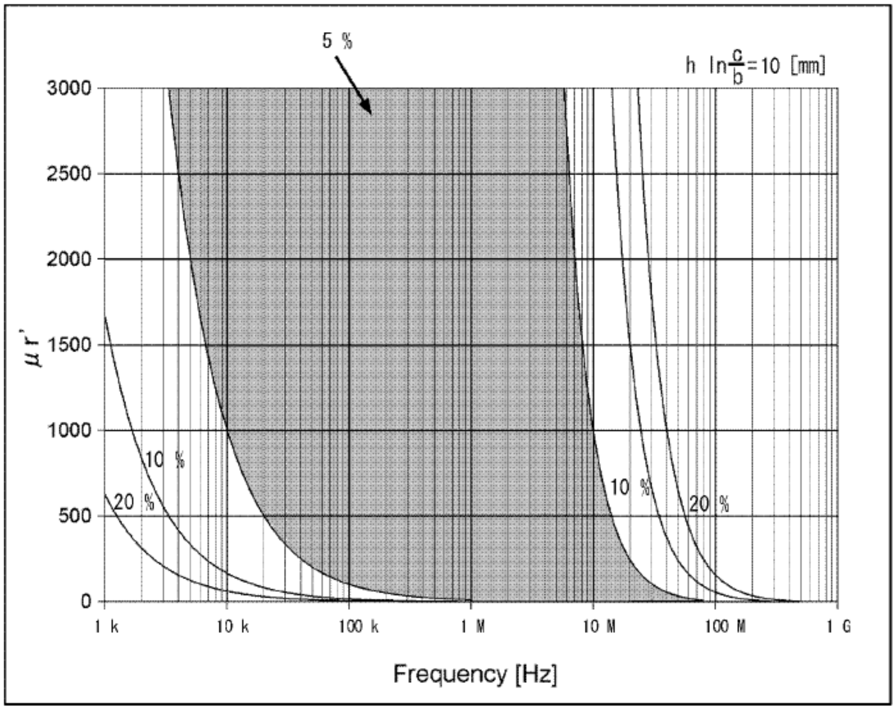


Figure 1-8 Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @F[1]=3)



1. $F = h \ln\frac{c}{b}$

Figure 1-9 Typical Permeability Measurement Accuracy (μ_r v.s. Frequency, @F[1]=10)



1. $F = h \ln\frac{c}{b}$

2 Initial Inspection

Introduction

This chapter contains the following information:

- Initial inspection.
- Repackaging the test fixture for shipment.

Initial Inspection

The magnetic material test fixture has been carefully inspected before being shipped from the factory. It should be in perfect physical condition, no scratches, dents or the like. It should also be in perfect electrical condition. Verify this by carefully performing an incoming inspection to check the magnetic material test fixture set for signs of physical damage and missing contents. If any discrepancy is found, notify the carrier and Keysight Technologies. Your Keysight Technologies sales office will arrange for repair and replacement without waiting for the claim to be settled.

- Inspect the shipping container for damage. Keep the shipping materials until the inspection is completed.
- Verify that the shipping container contains everything listed in Table 2-1.
- Inspect the exterior of the 16454A for any signs of damage.

Initial Inspection

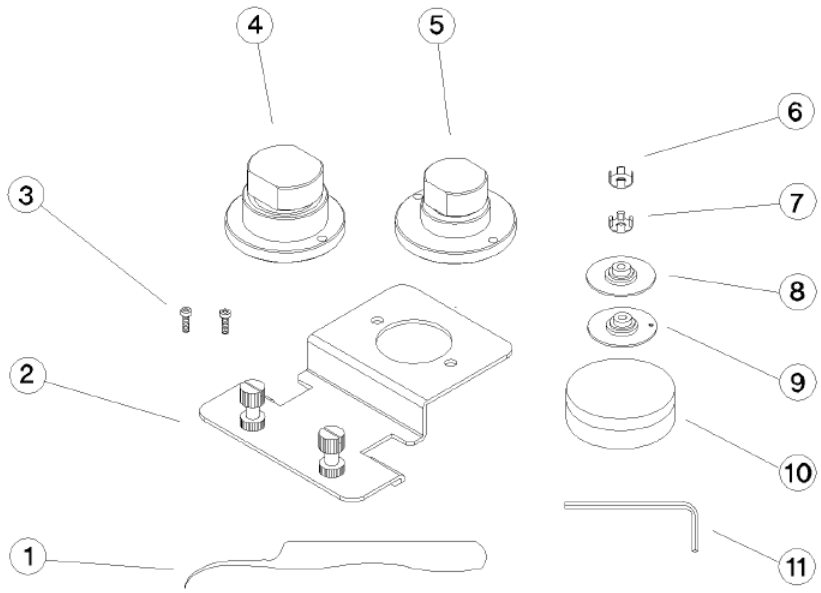


Table 2-1 16454A Contents

Ref /D	Part Number	Qty	Description	RoHS Compliant Replacement Part	Qty
1	8710-2081	1	Tweezers	8710-2081	1
2	16454-00601	1	Fixture Holder	16454-00601	1
3	0515-1050	2	Screw, Hex Recess	0515-1050	2
4	(not assigned)	1	Test Fixture (Large)	(not assigned)	1
5	(not assigned)	1	Test Fixture (Small)	(not assigned)	1
6	16454-25002	1	Holder A	16454-25002	1
7	16454-25001	1	Holder B	16454-25001	1
8	16454-25004	1	Holder C (WITHOUT HOLE)	16454-25004	1
9	16454-25003	1	Holder D (WITH HOLE)	16454-25003	1
10	1540-0622	1	Holder Case	9300-2603	1
11	5188-4452	1	Hex Key, 2.5mm Across Flats	5188-4452	1
-	16454-60101	1	Carrying Case[1]	16454-60101	1
-	16454-90020	1	Operation and Service Manual[1,2]	16454-90020	1

1. These parts are not shown in this figure.
2. Only available for option ABA.

Repackaging the Test Fixture For Shipment

If shipment to a Keysight Technologies service center is required, each test fixture should be repackaged using the original factory packaging materials.

If this material is not available, comparable packaging materials may be used. Wrap the magnetic material test fixture in heavy paper and pack in anti-static plastic packing material.Use sufficient shock absorbing material on all sides of the 16454A to provide a thick, firm cushion and to prevent movement. Seal the shipping container securely and mark it FRAGILE.

3 Theory on Material Measurement

This chapter explains the basic principle and the concept of material measurement.

Magnetic Material Measurement

Permeability Definition

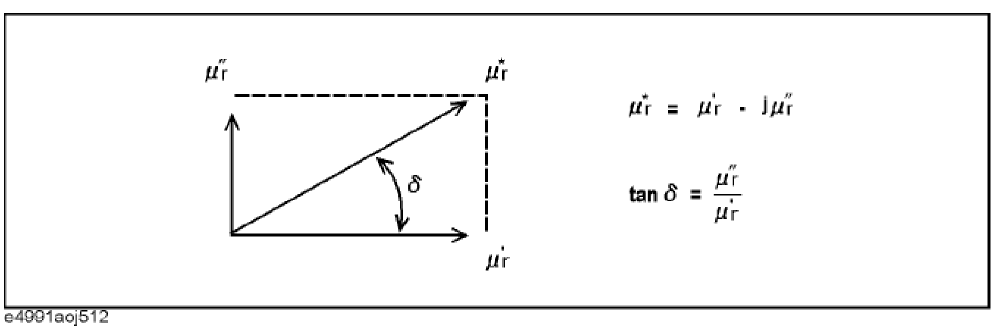
Permeability in the alternating-current magnetic field is defined as complex relative permeability (μ^*_r) (See Equation 3-1). The real component of the complex relative permeability (μ'_r) represents the amount of energy stored in the magnetic material from the alternating-current magnetic field. On the other hand, the imaginary component (μ''_r) indicates energy loss to the alternating current magnetic field.

Equation 3-1 Definition of Complex Relative Permeability

$$\mu^*_r = \mu'_r - j\mu''_r$$

As shown in Figure 3-1, complex relative permeability can be expressed in a vector diagram.The loss factor of a magnetic material is expressed as loss tangent (tan δ), which is the ratio of the imaginary component (μ''_r) to the real component (μ'_r) of the complex relative permeability.

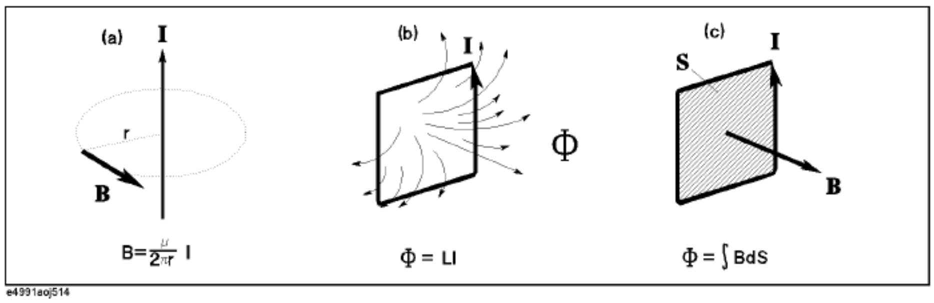
Figure 3-1 Vector Diagram of Complex Relative Permeability and Loss Tangent



Measurement Principle of Magnetic Material

When using a LCR meter or an Impedance Analyzer, the inductance measurement method is employed to measure complex relative permeability. In this method, a DUT (toroidal core) is coiled with a wire and relative permeability is calculated from the measured inductance values. This section explains the measurement principle when using the test fixture, 16454A.

Figure 3-2 Relationship among Current, Magnetic Flux, and Magnetic Flux Density



Generally, the magnetic flux density (B) induced by the current flowing in an infinitely long straight wire shown in (a) of Figure 3-2 is expressed as Equation 3-2.

Equation 3-2 Magnetic Flux Density Induced by Current Flowing in an Infinitely Long Straight Wire

$$B = \frac{\mu I}{2\pi r}$$

On the other hand, the magnetic flux (Φ) induced by current flowing in the closed loop shown in (b) of Figure 3-2 is expressed as Equation 3-3. Note that L indicates the self-inductance of the closed loop.

Equation 3-3 Magnetic Flux Induced by Current in Closed Loop

$$\Phi = LI$$

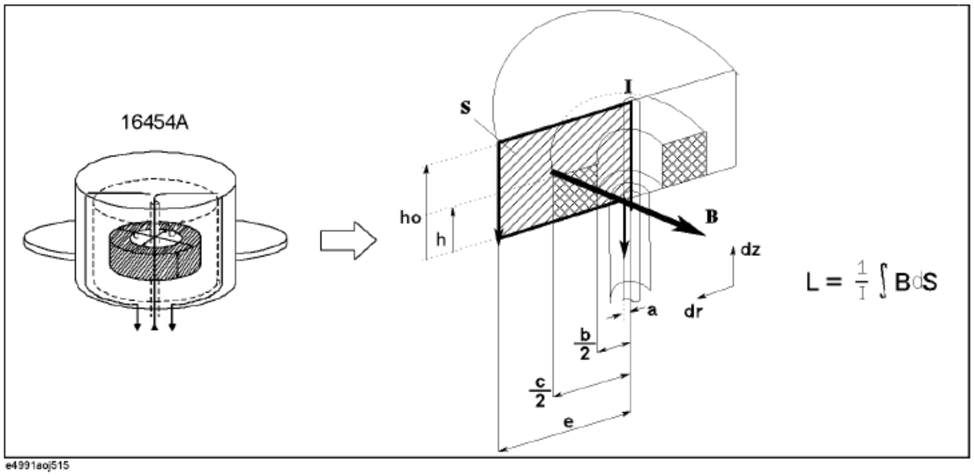
Furthermore, this magnetic flux (Φ) also can be expressed by integrating the magnetic flux density (B) throughout the enclosed surface, as shown in Figure 3-2 (See Equation 3-4).

Equation 3-4 Relationship between Magnetic Flux and Magnetic Flux Density

$$\Phi = \int B ds$$

When a DUT (toroidal core) is mounted in 16454A, an ideal (no magnetic flux leakage) one turn inductor is formed, as shown in Figure 3-3.

Figure 3-3 Measurement Principle When Using 16454A Test Fixture



The self-inductance of the measurement circuit including the DUT is derived as Equation 3-5 fromEquation 3-2, Equation 3-3, Equation 3-4, and the physical shape of 16454A.

Equation 3-5 Self-Inductance of Measurement Circuit

$$L = \frac{1}{I}\int Bds = \int_a^e \int_0^{h_0} \frac{\mu}{2\pi r} drdz$$

By unfolding Equation 3-5 with μ_0 as permeability of free space and μ_r as relative permeability of the DUT, Equation 3-6 can be obtained.

Equation 3-6 Self Inductance of Measurement Circuit

$$L = \int_{\frac{c}{2}}^{e}\int_0^{h_0} \frac{\mu_0}{2\pi r} drdz + \int_{\frac{b}{2}}^{\frac{c}{2}}\int_0^{h_0} \frac{\mu_0\mu_r}{2\pi r} drdz + \int_{\frac{b}{2}}^{\frac{c}{2}}\int_h^{h_0} \frac{\mu_0}{2\pi r} drdz + \int_a^{\frac{b}{2}}\int_0^{h_0} \frac{\mu_0}{2\pi r} drdz$$

By further unfolding Equation 3-6, Equation 3-7can be obtained.

Equation 3-7 Self Inductance of Measurement Circuit

$$L = \frac{\mu_0}{2\pi}\left\{(\mu_r - 1)h \ln\frac{c}{b} + h_0 \ln\frac{e}{a}\right\}$$

By transforming Equation 3-7 to calculate the relative permeability (μ_r) of the DUT, Equation 3-8 can be obtained.

Equation 3-8 Relative Permeability of DUT

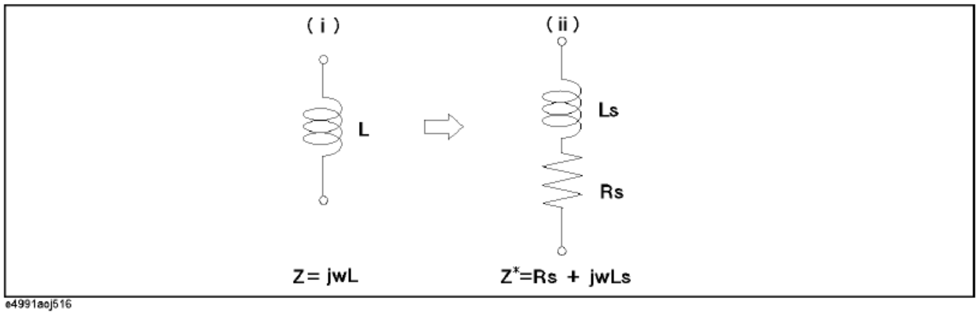
$$\mu_r = \frac{2\pi(L - L_{ss})}{\mu_0 h \ln\frac{c}{b}} + 1$$

L_{ss} in Equation 3-9 indicates the self-inductance when a DUT is not mounted in the test fixture.

Equation 3-9 Self-Inductance When DUT Is Not Mounted in Test Fixture

$$L_{ss} = \frac{\mu_0}{2\pi} h_0 \ln \frac{e}{a}$$

Figure 3-4 Loss of Magnetic Material



The impedance Z of the circuit (i) in Figure 3-4 is expressed as Equation 3-10, and the complex impedance Z* of the circuit (ii) is expressed as Equation 3-11.

Equation 3-10 Impedance of Circuit (i)

$$Z = j\omega L$$

Equation 3-11 Complex Impedance of Circuit (ii)

$$Z^* = R_s + j\omega L_s = j\omega\left(\frac{R_s}{j\omega} + L_s\right)$$

As alternating current causes inductance loss, the self-inductance L of the measurement circuit is expressed as complex impedance, as shown in Equation 3-12.

Equation 3-12 Self-Inductance of Measurement Circuit Expressed as Complex Impedance

$$L = \frac{Z^*}{j\omega}$$

Substituting “L” from Equation 3-12 to Equation 3-8 yields Equation 3-13.

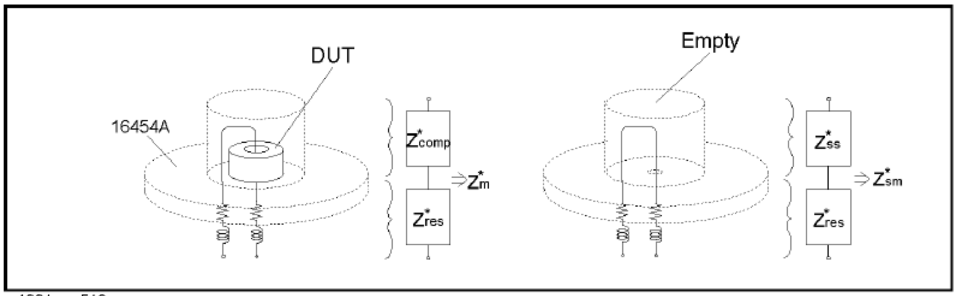
Equation 3-13 Complex Relative Permeability of DUT

$$\mu_r^* = \frac{2\pi(Z^* - j\omega L_{ss})}{j\omega\mu_0 h \ln\frac{c}{b}} + 1$$

Structure of 16454A Test Fixture

As shown in Figure 3-5, 16454A has a residual impedance Z^*_{res}.

Figure 3-5 16454A Residual Impedance



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Given the ideal impedance Z^*_{ss} of the 16454A text fixture with no DUT mounted, the residual impedance Z^*_{res} can be calculated from the measured impedance Z^*_{sm} with no DUT mounted in 16454A (in SHORT state).

Equation 3-14 16454A Residual Impedance

$$Z^*_{res} = Z^*_{sm} - Z^*_{ss}$$

Errors due to residual impedance can be minimized by SHORT compensation. The impedance after error compensation Z^*_{comp} can be calculated from the measured impedance Z^*_m with a DUT mounted in 16454A, as shown in Equation 3-15.

Equation 3-15 Compensated Impedance

$$Z^*_{comp} = Z^*_m - Z^*_{res}$$

Assuming that Z^*_{ss} consists only of inductance elements ($Z^*_{ss} = j\omega L_{ss}$), the complex relative permeability of the DUT can be calculated using Equation 3-13 and compensated impedance, $Z^*_{comp} = Z^*$, as shown in Equation 3-16.

Equation 3-16 Complex Permeability of DUT

$$\mu^*_r = \frac{2\pi(Z^*_m - Z^*_{sm})}{j\omega\mu_0 h \ln\frac{c}{b}} + 1$$

4 Operation

Connecting the Test Fixture

Selecting Fixture and Holder

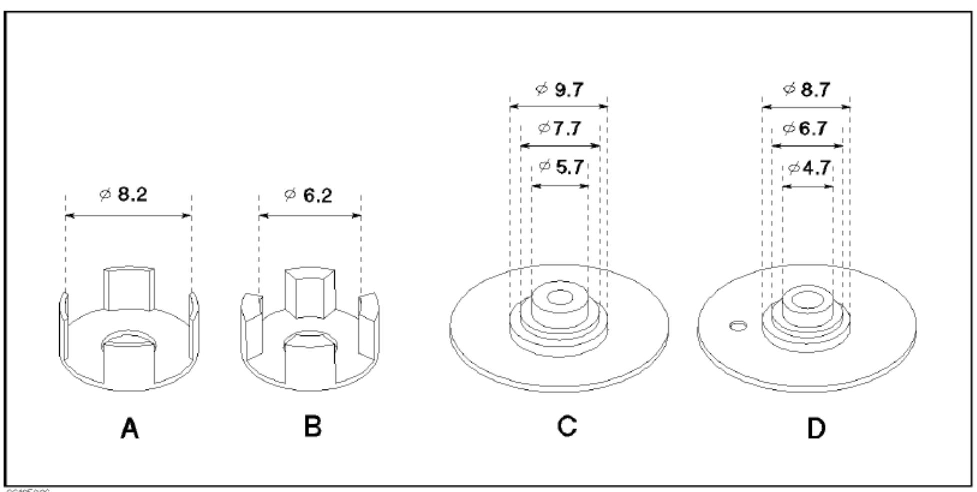
The 16454A consists of two fixtures, a large one and a small one. The applicable MUT size for each fixture is listed in Table 4-1.

Table 4-1 **MUT Size for Test Fixtures**

Fixture	Small		Large	
Holder	A	B	C	D
MUT Outer Diameter (mm)	≤ ϕ8mm	≤ ϕ6mm	≤ ϕ20mm	≤ ϕ20mm
MUT Inner Diameter (mm)	≥ ϕ3.1mm	≥ ϕ3.1mm	≥ ϕ6mm	≥ ϕ5mm
MUT Height (mm)	≤ 3mm	≤ 3mm	≤ 8.5mm	≤ 8.5mm

Figure 4-1 shows the dimensions of the MUT holder.

Figure 4-1 Dimensions of the MUT Holder



Connecting the Test Fixture to the Test Head

To connect your fixture to the Test Head, perform the following steps:

1. Turn the APC-7® connector on the test head as shown in Figure 4-2.
2. Verify that the connector sleeve is retracted fully as shown in Figure 4-3.

Figure 4-2

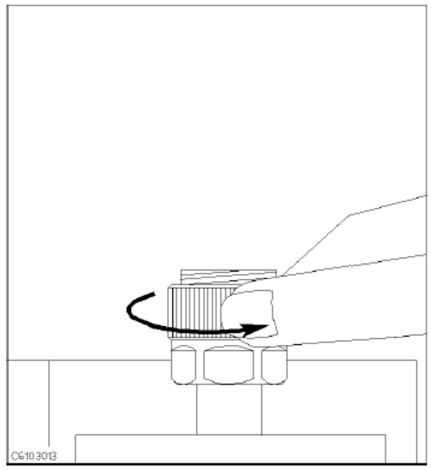
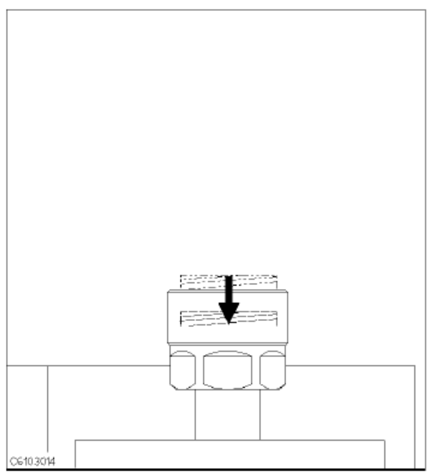
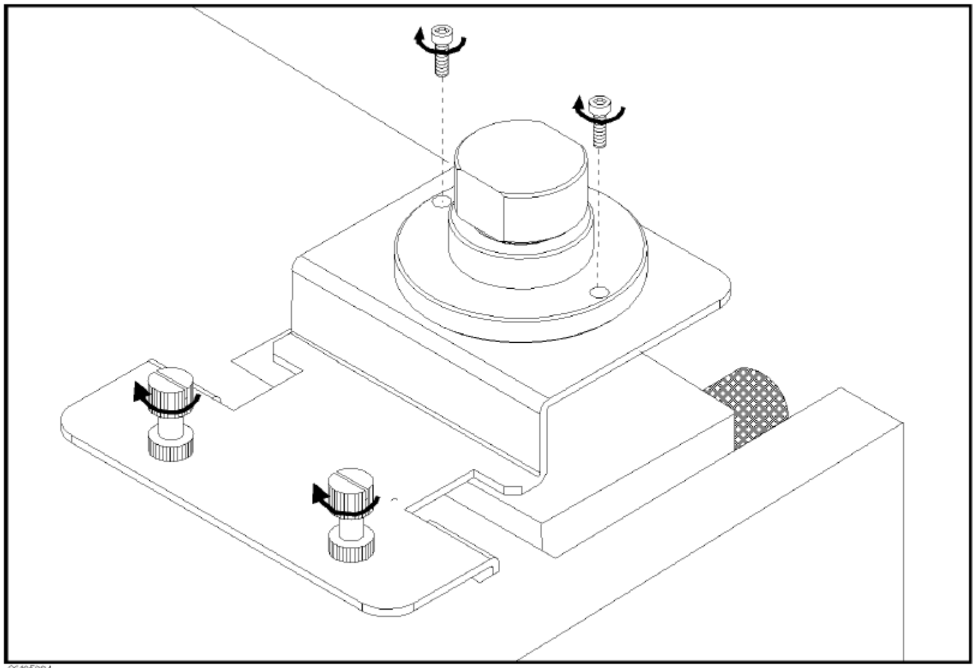


Figure 4-3



3. Secure the test fixture to the fixture holder using the two screws.
4. Connect the connector on the underside of the test fixture to the APC-7 connector on the test head.
5. Secure the fixture holder to the test station using the two screws.

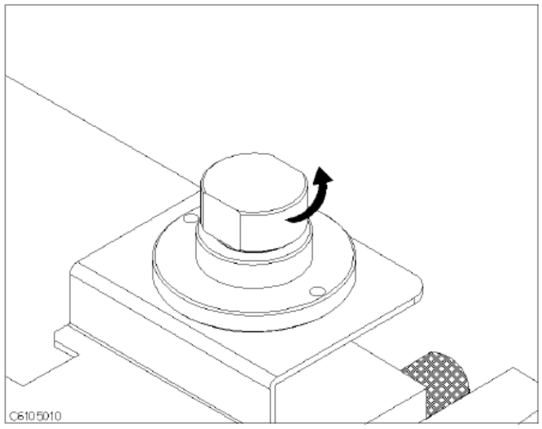
Figure 4-4 Connecting the Test Fixtures (16454A Small)



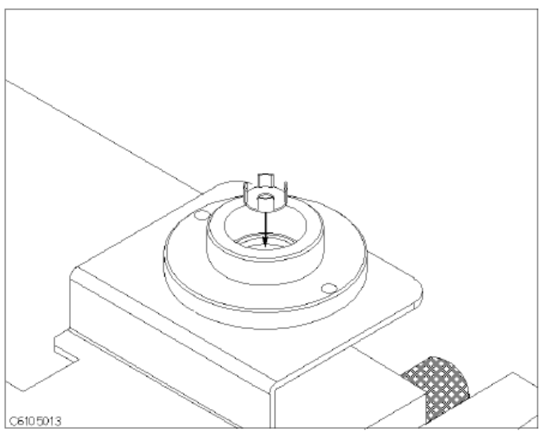
Performing SHORT Compensation

The SHORT Compensation corrects for the residual impedance due to the test fixture.

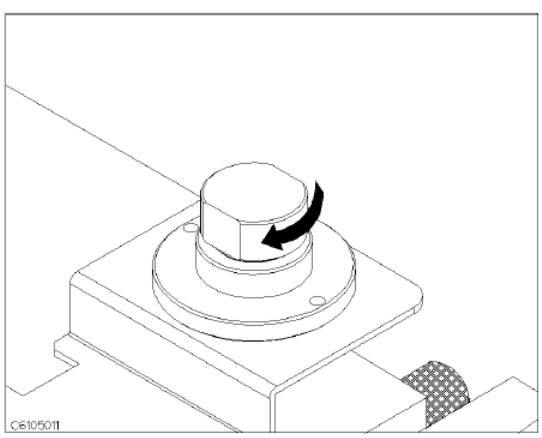
1. Remove the cap of the fixture.



2. Place a MUT holder only in the fixture.



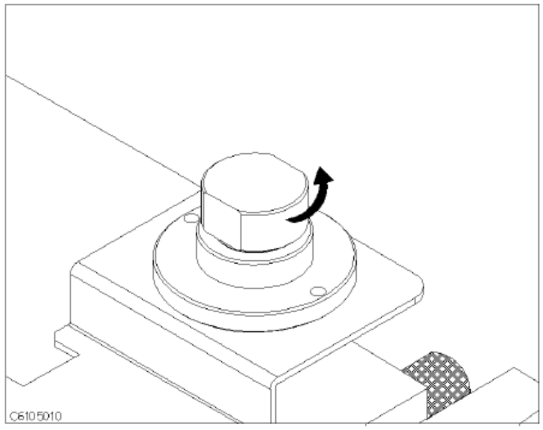
3. Replace the cap by screwing tightly.



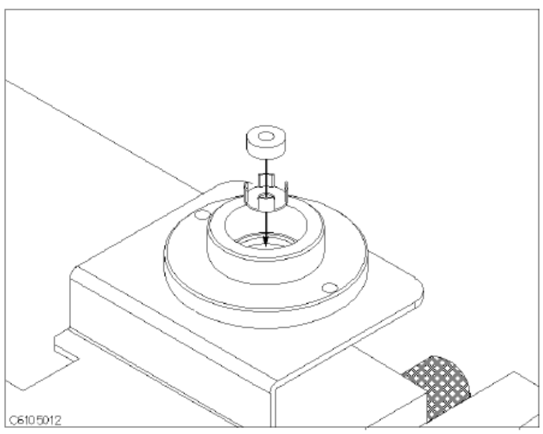
Placing the MUT into the Test Fixture

How to place the MUT on the 16454A is shown below:

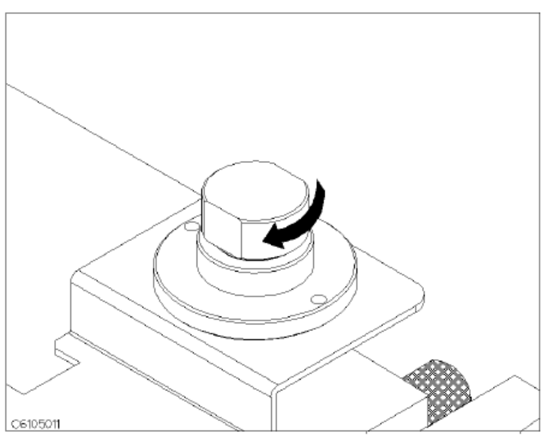
1. Remove the cap of the fixture.



2. Place a MUT onto the MUT holder and insert it into the fixture.



3. Replace the cap by screwing tightly.



5 Service

Introduction

This chapter gives the service information for the 16454A Magnetic Material Test Fixture.

Serial Number for Non-RoHS 16454A:
“MY43100001 – MY43200586” / “SG43100001 – SG43200586”

Serial Number for RoHS 16454A:
“MY43200587/SG43200587 and above”

Replaceable Parts

Table 5-1 identify the supported parts and their respective RoHS compliant replacement support part. Due to limited availability of RoHS compliance station and technical difficulties in RoHS soldering, only parts and support level that do not require RoHS soldering are supported. Replace all defective parts with RoHS compliance part number. The parts listed in this table can be ordered from your nearest Keysight Technologies office. Ordering information should include the Keysight part number and the quantity required.

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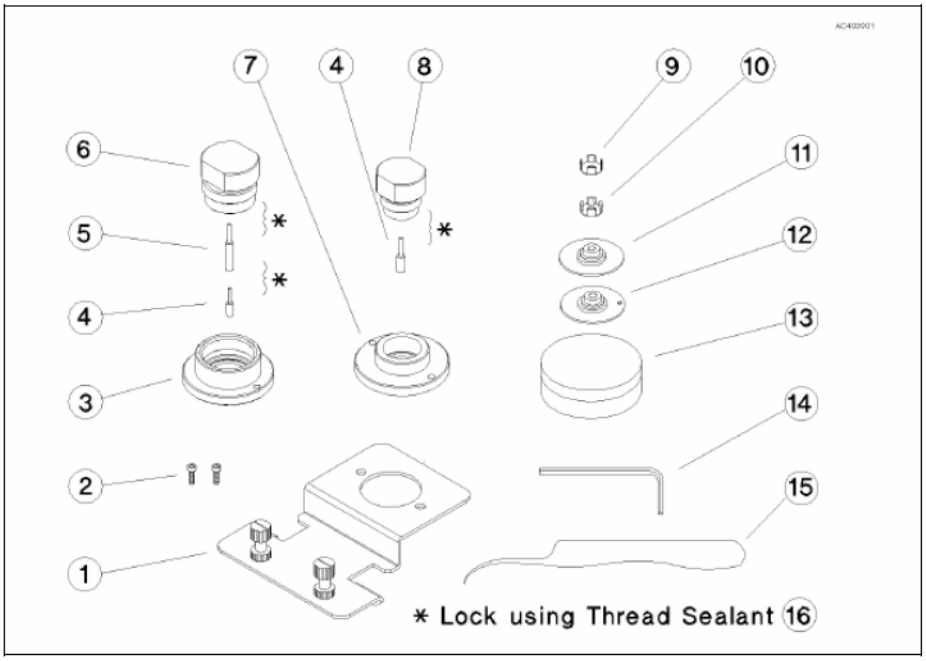

Table 5-1 Replaceable Parts List

Ref /D	Part Number	Qty	Description	RoHS Compliant Replaceable Part	Qty
1	16454-00601	1	Length Positioning Stage Assembly	16454-00601	1
2	0515-1050	2	Screw, Hex Recess	0515-1050	2
3	16454-23004	1	Fixture Flange (Large)	16454-23004	1
4	1250-0816	2	Conn-RF Conn	1250-0816	2
5	16454-23005	1	Center Pin	16454-23005	1
6	16454-23003	1	Fixture Cap (Large)	16454-23003	1
7	16454-23002	1	Fixture Flange (Small)	16454-23002	1
8	16454-23001	1	Fixture Cap (Small)	16454-23001	1
9	16454-25002	1	Holder A	16454-25002	1
10	16454-25001	1	Holder B	16454-25001	1
11	16454-25004	1	Holder C (WITHOUT HOLE)	16454-25004	1
12	16454-25003	1	Holder D (WITH HOLE)	16454-25003	1

Table 5-1 Replaceable Parts List

Ref /D	Part Number	Qty	Description	RoHS Compliant Replaceable Part	Qty
13	1540-0622	1	Holder Case	9300-2603	1
14	5188-4452	1	Hex Key, 2.5mm Across Flats	5188-4452	1
15	8710-2081	1	Tweezers	8710-2081	1
16	0470-0013	1	Thread Sealant	0470-0013	1
-	16454-60101	1	Carrying Case[1]	16454-60101	1

1. These parts are not shown in this figure.

Functional Test

This section provides the functional test procedure to check the 16454A performance. The functional test can be used for post repair function verification.

Fixture Impedance Check

1. Perform calibration at the APC-7® terminal of the measurement instrument.

2. Place the fixture (small) on the calibrated APC-7® terminal of the measurement instrument.

3.Read L_S and R_S value for each test fixture. The guideline is as follows:

Table 5-2 **Fixture Impedance Check Guideline**

Fixture	Frequency	Parameter	Guideline
Small	100MHz	L_S	1nH ± 0.5nH
		R_S	<100mΩ
Large	100MHz	L_S	5.5nH ± 2.5nH
		R_S	<300mΩ

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This information is subject to change without notice.

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