User's Manual

HYSTERESIS LOOP TRACER
Model: HLT-111
(Rev 01/04/2010)

Manufactured by:
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CE

ISO 9001:2015
Certified Company

CONTENTS

COPYRIGHT AND WARRANTY

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COPYRIGHT NOTICE

LIMITED WARRANTY

SES Instruments Pvt. Ltd warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. SES Instruments Pvt. Ltd will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of manufacturing defect or improper use by the customer shall be made solely by SES Instruments Pvt. Ltd. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packaging of the equipment for return shipment will not be covered by the warranty). Shipping costs for returning the equipment, after repair, will be paid by SES Instruments Pvt. Ltd.

EQUIPMENT RETURN

Should this product have to be returned to SES Instruments Pvt. Ltd, for whatever reason, notify SES Instruments Pvt. Ltd BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

Note : No equipment will be accepted for return without an authorization.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

1. The carton must be strong enough for the item shipped.
2. Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
3. Make certain that the packing material can not displace in the box, or get compressed, thus letting the instrument come in contact with the edge of the box.

SAFETY INFORMATION

This Section addresses safety considerations and describes symbols that may appear on the Instrument or in the manual.

A **Warning** Statement identifies conditions or practices that could result in injury or death. A **Caution** statement identifies conditions or practices that could result in damage to the Instrument or equipment to which it is connected.

 **Warning**

> **To avoid electric shock, personal injury, or death, carefully read the information in Table-1, “Safety Information,” before attempting to install, use, or service the Instrument.**

GENERAL SAFETY SUMMARY

This equipment is Class 1 equipment tested in accordance with the European Standard publication EN 61010-1.

This manual contains information and warnings that must be observed to keep the Instrument in a safe condition and ensure safe operation.

To use the Instrument correctly and safely, read and follow the precautions in Table 1 and follow all safety instructions or warnings given throughout this manual that relate to specific measurement functions. In addition, follow all generally accepted safety practices and procedures required when working with and around electricity.

SYMBOLS

Table 2 lists safety and electrical symbols that appear on the Instrument or in this manual.

Table 2. Safety and Electrical Symbols

Symbols	Description	Symbols	Description
	Risk of danger. Important information. See Manual.		Earth ground
	Hazardous voltage. Voltage >30Vdc or ac peak might be present.		Potentially hazardous voltage
	Static awareness. Static discharge can damage parts.		Do not dispose of this product as unsorted municipal waste. Contact SES or a qualified recycle for disposal.

Table 1. Safety Information

Warning

To avoid possible electric shock, personal injury, or death, read the following before using the Instrument:

- **Use the Instrument only as specified in this manual, or the protection provided by the Instrument might be impaired.**
- **Do not use the Instrument in wet environments**
- **Inspect the Instrument in wet environments.**
- **Inspect the Instrument before using it. Do not use the Instrument if it appears damaged.**
- **Inspect the connecting lead before use. Do not use them if insulation is damaged or metal is exposed. Check the connecting leads for continuity. Replace damaged connecting leads before using the Instrument.**
- **Whenever it is likely that safety protection has been impaired, make the Instrument inoperative and secure it against any unintended operation.**
- **Have the Instrument serviced only by qualified service personnel.**
- **Always use the power cord and connector appropriate for the voltage and outlet of he country or location in which you are working.**
- **Never remove the cover or open the case of the Instrument before without first removing it from the main power source.**
- **Never operate the Instrument with the cover removed or the case open.**
- **Use only the replacement fuses specified by the manual.**
- **Do not operate the Instrument around explosive gas, vapor or dust.**
- **When servicing the Instrument, use only specified replacement parts.**
- **The equipment can remain Switched on continuously for five hours**
- **The equipment must remain Switched off for at lease fifteen minutes before being switched on again.**
- **The equipment is only for the intended use**
- **Use the equipment only as specified in this manual.**

Unpacking and Inspecting the Instrument

Every care is taken in the choice of packing material to ensure that your Instrument will reach you in perfect condition. If the Instrument has been subject to excessive handling in transit, there may be visible external damage to the shipping container and packing material for the carrier's inspection.

Carefully unpack the Instrument from its shipping container and inspect the contents for damaged or missing items. If the Instrument appears damaged or something is missing, contacts the carrier and SES immediately. Save the container and packing material in case you have to return the Instrument.

Storing and Shipping the Instrument

To prepare the Instrument for storage or shipping, if possible, use the original shipping container alongwith thermocoal corners, as it provides shock isolation for normal handling operations. If the original shipping container is not available, use any good cardboard box which is at least 2-3 inches bigger than the instrument on all sides, with cushioning material (thermocoal or styrofoam etc) that fills the space between the instrument and the side of this box.

To store the Instrument, place the box under cover in a location that complies with the storage environment specification described in the "Environment Sections" below.

Environment

Temperature

Operating …………………………………. 0°C to 50°C
Storage …………………………………… 40°C to 70°C
Warm Up …………………………………15 min to full uncertainty specification

Relatively Humidity (non-condensing)

Operating ………………………………….Uncontrolled (<10°C)
<90 % (10°C to 30°C)
<75 % (30°C to 40°C)
<45 % (40°C to 50°C)
Storage………………………………….. -10°C to 60°C <95 %

Power Considerations

The Instrument operates on varying power distribution standards found throughout the world and must be set up to operate on the line voltage that will power it. The Instrument is packed ready for use with a line voltage determined at the time of ordering.

Replacing the Fuses

The Instrument uses one fuse to protect the line-power input and two fuses to protect current-measurement inputs.

Line-Power Fuse

The Instrument has a line-power fuse in series with the power supply. Table 3 indicates the proper fuse for each of the four line-voltage selections. The line-power fuse is accessed through the real panel.

1. Unplug the power cord.
2. Rotate the fuse holder cap to the right until the fuse POPS out.
3. Remove the fuse and replace it with a fuse of an appropriate rating for the selected line-power voltage. See Table 3.

⚠ ⚠ **Warning**

To avoid electric shock or fire, do not use makeshift fuses or short-circuit the fuse holder.

Table 3. Line Voltage to Fuse Rating

Line Voltage Selection	Fuse Rating
220/ 240 V	1A, 250V (Slow blow)
100/ 120 V	2A, 250V (Slow blow)

Connecting to Line Power

⚠ ⚠ **Warning**

To avoid shock hazard, connect the factory supplies three conductor line power cord to a properly grounded power outlet. Do not use a two-conductor adapter or extension cord, as this will break the protective ground connection. If a two conductor power cord must be used, a protective grounding wire must be connected between the ground terminal and earth ground before connecting the power cord or operating the Instrument.

1. Verify that the Line voltage is set to the correct setting.
2. Verify that the correct fuse for the line voltage is installed.
3. Connect the power cord to a properly grounded three-prong outlet. See Figure 3 for line-power cord types available from SES. Refer to Table 4 for description of the line-power cords.

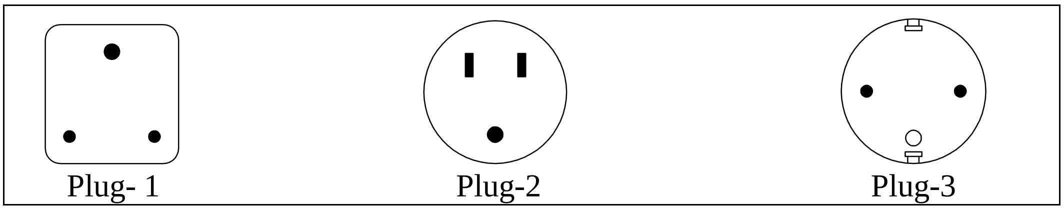


Figure 3. Line-Power Cord Types Available from SES

Table 4. Line-Power Cord Types Available from SES

Type	Voltage/Current	SES Model Number
India	240 V/ 5 A	Plug-1
North America	120 V/15 A	Plug-2
Universal Euro	220 V/16 A	Plug-3

Turning Power On

The On-Off switch on the front panel when points towards “ON” signs, indicates that the equipment has been switched on.

Cleaning the Instrument

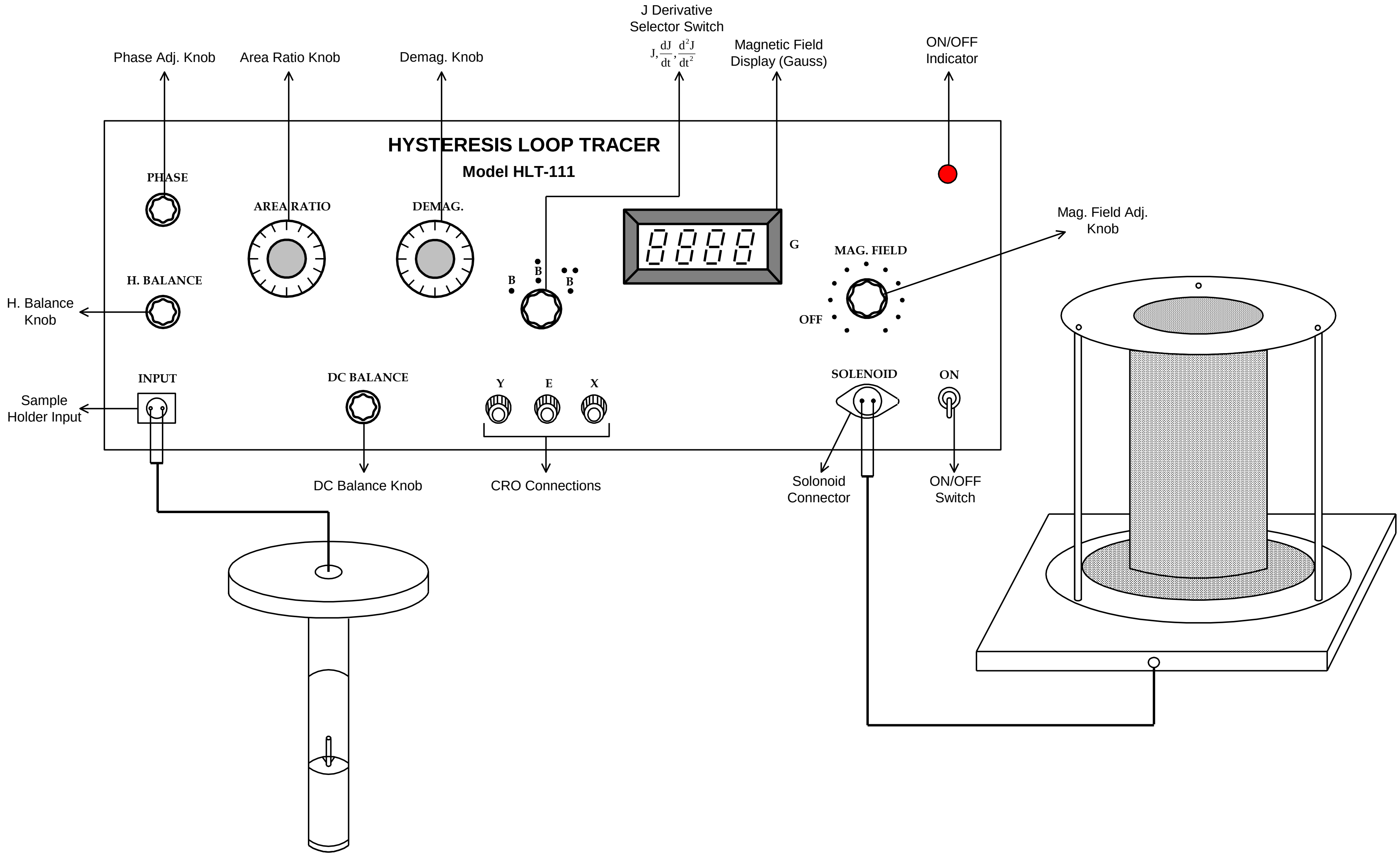
⚠ ⚠ **Warning**

To avoid electric shock or damage to the Instrument, never get water inside the Instrument.

⚠ **Caution**

To avoid damaging the Instrument’s housing, do not apply solvents to the Instrument.

If the Instrument requires cleaning, wipe it down with a cloth that is lightly dampened with water or a mild detergent. Do not use aromatic hydrocarbons, alcohol, chlorinated solvents, or methanol-based fluids when wiping down the Instrument.



Panel Diagtram of Hysteresis Loop Tarcer, HLT-111

INTRODUCTION

A precise knowledge of various magnetic parameters of ferromagnetic substances and the ability to determine them accurately are important aspects of magnetic studies. These not only have academic significance but are also indispensable for both the manufacturers and users of magnetic materials.

The characteristics which are usually used to define the quality of the substance are coercivity, retentivity, saturation magnetisation and hysteresis loss. Furthermore, the understanding of the behaviour of these substances and improvement in their quality demand that the number of magnetic phases present in a system is also known.

The information about the aforementioned properties can be obtained from a magnetisation hysteresis loop which can be traced by a number of methods in addition to the slow and laborious ballistic galvanometer method. Among the typical representatives of AC hysteresis loop tracers some require the ring form of samples, while others can be used with thin films, wires or even rock and mineral samples. Toroidal or ring form samples are more convenient because of the absence of demagnetising effect due to closed magnetic circuits, but are not practicable to make all test samples in toroidal form with no free ends. Further every time the pickup and magnetising coils has to be wounded on them and hence are quite inconvenient and time consuming. In the case of open circuit samples, the free end polarities gives rise to demagnetising field which reduces the local field acting in the specimen and also makes the surrounding field non-uniform. Therefore, it becomes necessary to account for this effect lest the hysteresis loop is sheared. In case of conducting ferromagnetism, several additional problems arises due to eddy currents originating from the periodic changes in applied magnetic field. These currents give rise to a magnetic field in the sample which counteracts the variation of the external field and, in turn, renders the field acting in it non uniform and different from the applied field, both in magnitude and phase. Thus apart from resistive heating of the samples, because of the eddy currents the forward and backward paths traced near saturation will be different, which will lead to a small loop instead of a horizontal line in the magnetic polarisation (J) against field (H) plot Fig. 1. The intercept of the magnetic polarization axis, which corresponds to retentivity and saturation magnetic polarization tip will continue to increase with applied field upto very high values. Accordingly, retentivity (J_r) and saturation magnetic polarization (J_s) will be asymptotic values of the J-intercept and tip height respectively against H plots. Furthermore, the width of the loop along the direction of the applied field will depend on its magnitude and will continue to increase because shielding due to eddy currents is proportional to the external field. Therefore, the true value to coercivity (JH_c) corresponding to no eddy currents situation, will be obtained by extrapolating the half loop width against field line to the H=0 axis. Obviously the effect of eddy currents will be more pronounced in thicker samples than in thin ones.

PACKING LIST

1. Hysteresis Loop Tracer, HLT-111 (Main unit)
2. Solenoid
3. Sample Holder
4. Sample Set (Hard Steel, Mild Steel, Com. Nickel in Wire form)

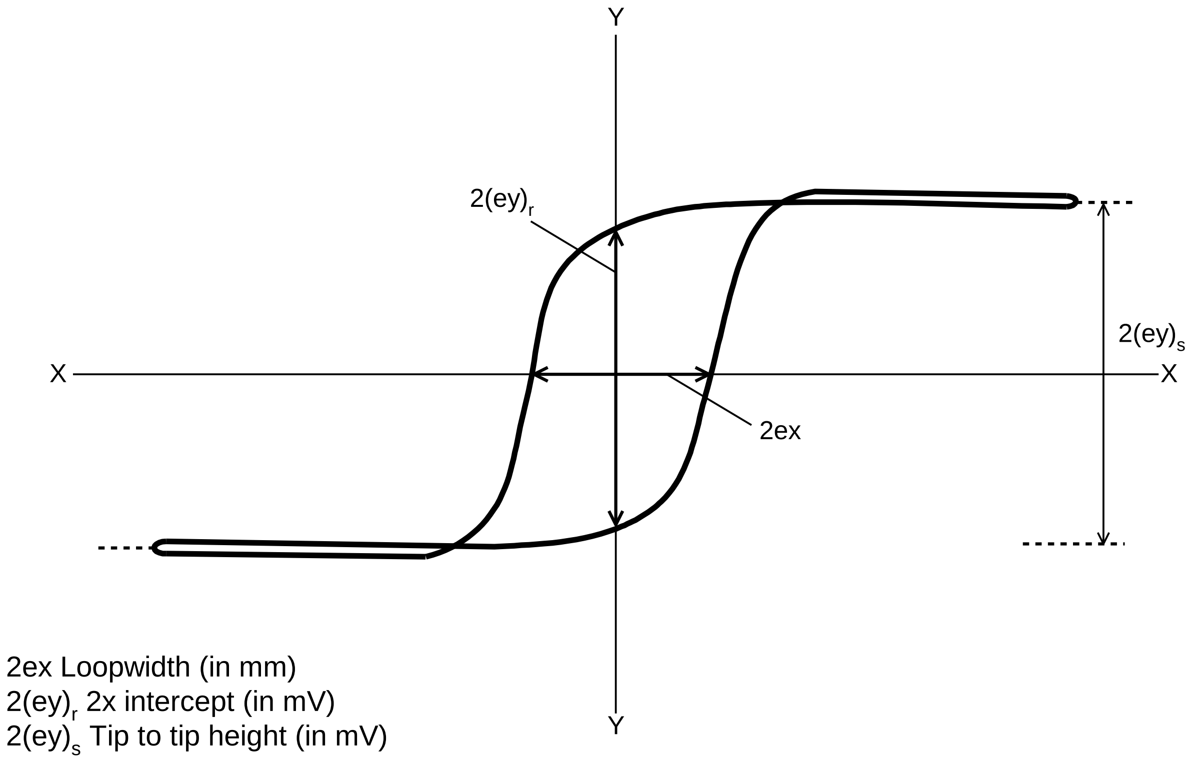


Fig. 1

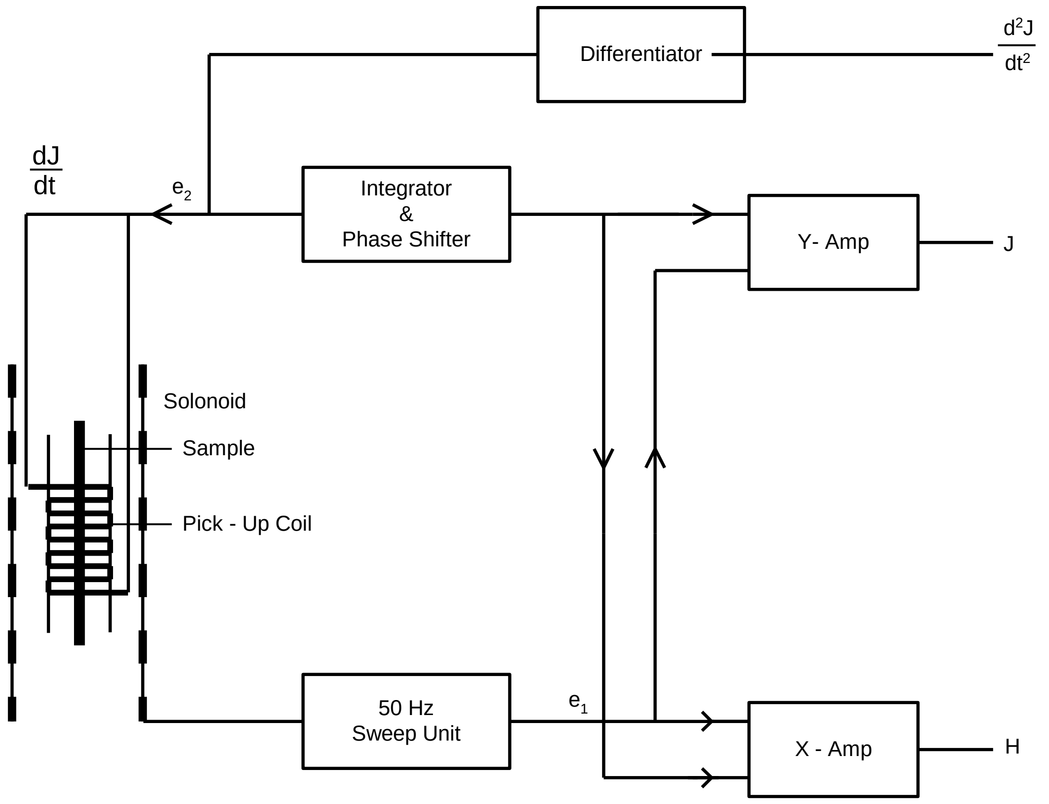


Fig. 2: Block Diagram of Hysteresis Loop Tracer

DESIGN PRINCIPLE

When a cylindrical sample is placed coaxially in a periodically varying magnetic field (say by the solenoid) Fig. 2 the magnetisation in the sample also undergoes a periodic variation. This variation can be picked up by a pick up coil which is placed coaxially with the sample. Normally, the pickup coil is wound near the central part of the sample so that the demagnetisation factors involved are ballistic rather than the magnetometric.

For the uniform field H_a produced, the effective field H acting in the cylindrical sample will be

$H = H_a - NM$ where M is the magnetisation, or

$$H = H_a - \frac{NJ}{\mu_0} \qquad (1)$$

where N is the normalised demagnetisation factor including 4π and J is the magnetic polarization defined by

$$B = \mu_0 H + J \qquad (2)$$

with $B=\mu H$ or $\mu_0(H+M)$ as magnetic induction. The signal corresponding to the applied field, H_a, can be written as

$$e_1 = C_1 H_a \qquad (3)$$

where C_1 is a constant.

Further the flux linked with the pickup coil of area A_c due to sample of area A_s will be

$$\phi = \mu_0(A_c - A_s)H' + A_s B$$

Here H' is the magnetic field, in the free from sample area of the pickup coil, will be different from H and the difference will be determined by the magnitude of demagnetising field. However, when the ratio of length of the sample rod to the diameter of the pickup coil is more than 10, the difference between H and H' is too small, so that $\phi = \mu_0(A_c - A_s)H + A_s B$

$$= \mu_0 A_c H + A_s(B - \mu_0 H)$$

$$\Rightarrow \phi = \mu_0 A_c H + A_s J \qquad (4)$$

The signal e_2 induced in the pickup coil will be proportional to $\frac{d\phi}{dt}$

After integration the signal (e_3) will, therefore be

$$e_3 = C_3\phi = C_3\mu_0 A_c H + C_3 A_s J \qquad (5)$$

Solving equations (1), (3) and (5) for J and H give

$$C_1 C_3 A_c \left(\frac{A_s}{A_c} - N\right) J = C_1 e_3 - \mu_0 C_3 A_c e_1 \qquad (6)$$

and $$C_1 C_3 A_c \left(\frac{A_s}{A_c} - N\right) H = C_3 A_s e_1 - \frac{N C_1 e_3}{\mu_0} \qquad (7)$$

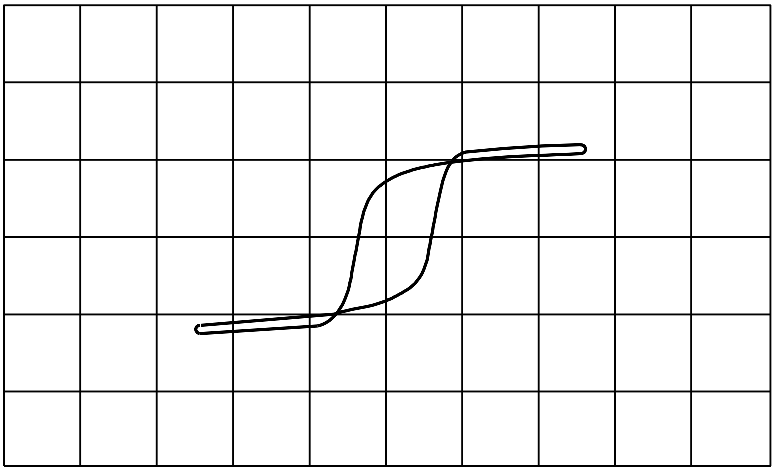


Fig. 3 (a) : J-H Loop

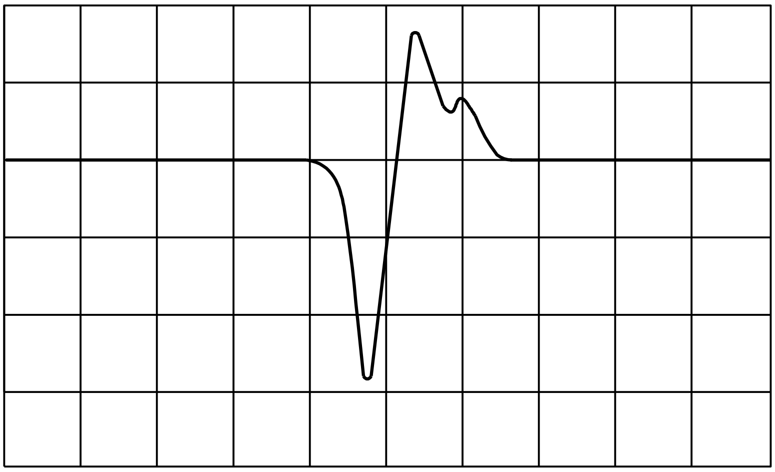


Fig. 3 (b) : $\frac{d^2J}{dt^2}$ Showing Two Magnetic Phase

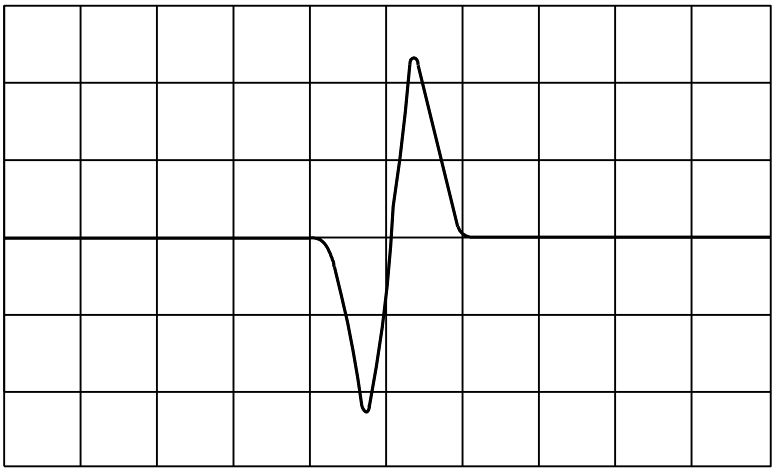


Fig. 3 (c) : $\frac{d^2J}{dt^2}$ Showing a Single Magnetic Phase in The Sample

Based on these equations an electronic circuit may be designed to give the values of J and H and hence the hysteresis loop.

In case the sample contains a number of magnetically different constituents, the loop obtained will be the algebraic sum of individual loops of different phases. The separation of these is not easy in a J-H loop while in a second derivative of J, $\frac{d^2J}{dt^2}$, the identification can be made very clear.

EXPERIMENTAL DESIGN

The aim is to produce electrical signals corresponding to J and H as defined in Eqs. (6) and (7) so that they can be displayed on oscilloscope Fig. 3. Moreover, it should be able to display $\frac{d\phi}{dt}$ and $\frac{d^2\phi}{dt^2}$ as a function of H or usual time base of the CRO.

A detailed circuit diagram is as shown in schematic diagram at the end. The magnetic field has been obtained with a multilayered solenoid driven by the AC mains at 60 Hz and supplied through a variable transformer arrangement. The magnetic field has been calibrated with a Hall probe and is found to be within ±3% of the maximum value over a length of 5 cm. across the central region. The instantaneous current producing the field is passed through a resistor R_1 in series with the solenoid and measured with an AC ammeter. The resulting signal e_1 is applied across a 500Ω helipot and an adder amplifier through a 100 KΩ resistance.

The signal e_2 corresponding to the rate of change of flux is obtained from a pickup coil wound on a non conducting tube. Necessary arrangements have been made to place the sample coaxially with the pickup winding and in uniform magnetic field. The pick-up coil is connected to point B (Fig. 2) through twisted wires, where e_2 constitutes the input for further circuit. To obtain J, e_2 is fed to an adjustable gain integrator. Because of capacitive coupling of pickup coil and solenoid, self inductance of pickup coil and integration operation an additional phase will be introduced in the output signal e_3, whose sign can be made negative with respect to e_1 by interchanging the ends of the pickup coil. To render e_3 completely out of phase with e_1, a phase shifter consisting of a 1KΩ potentiometer and 1μF capacitor has been connected at the output of integrator. Amplitude attenuation due to this network is compensated by the gain of the integrator and is not important as addition of signals is performed afterwards.

The out of phase signals e_1 and e_3 are added at the input of a unity gain adder amplifier and its output which is proportional to J is applied to Y-input of a CRO. Fractions of these signals corresponding to the demagnetisation factor and area ratio form the input of another adder amplifier with gain 10 whose output after further amplification of 10 is fed to the X-input of CRO and gives H. It may be mentioned that the gains of the amplifier can be adjusted but should always be such that the operational amplifiers are not loaded to saturation.

The selector switch (SW) can change the Y-input of CRO to J, $\frac{dJ}{dt}$ or $\frac{d^2J}{dt^2}$. The $\frac{dJ}{dt}$ signal is taken directly from the pickup while $\frac{d^2J}{dt^2}$ is obtained through an operational amplifier differentiater.

ANALYSIS OF THE CIRCUIT

The magnetic field at the centre of the solenoid for current i flowing through it will be

$$H_a = Ki \tag{8}$$

also $$e_1 = R_1 i \tag{9}$$

with symbols defined above Eq. (9) reduces to Eq. (3) with $C_1=R_1/K$. Further, when the sample is placed in a pickup coil of n turns

$$e_2 = n\left(\frac{d\phi}{dt}\right)$$

$$= n\mu_0 A_c\left(\frac{dH}{dt}\right) + nA_s\left(\frac{dJ}{dt}\right) \tag{10}$$

by substituting ϕ from Eq. (4), we get

$$-e_3 = -g_1\int e_2 dt$$

$$= -g_1 n\mu_0 A_c H - g_1 n A_s J \tag{11}$$

Where g_1 is the gain of the integrator and phase shifter combination. The sum of e_1 and $-e_3$ after amplification becomes.

$$e_y = -g_y(e_1-e_3)$$

$$= -g_y(C_1 H - g_1 n\mu_0 A_c H + C_1 \frac{NJ}{\mu_0} - g_1 n A_s J) \tag{12}$$

Using Eq. (1), (3) and (11), g_y is the gain of this amplifier. If we adjust $C_1=g_1 n\mu_0 A_c$, then

$$e_y = g_y\, g_1 n A_c\left(\frac{A_s}{A_c} - N\right)J \tag{13}$$

Fraction α and β of e_1 and $-e_3$ respectively, are added together at the input of the first amplifier for the X-input. If g_x be the total gain of both amplifiers we get

$$e_x = g_x(e_1 - Be_3)$$

$$= g_x g_1 n\mu_0 A_c(-B)H + g_x g_1 n A_c(N - B\frac{A_s}{A_c})J \tag{14}$$

after substituting $C_1=g_1 n\mu_0 A_c$, J will be eliminated from the right hand side of (14). By adjusting $\alpha$and β such that

$$\alpha = \frac{A_s}{A_c} \text{ and } \beta=N \tag{15}$$

we get $$e_x = g_x g_1 n\mu_0 A_c(\frac{A_s}{A_c} - N)H \tag{16}$$

Equation (13) and (16) can be written as

$$H = G_0 \frac{e_x}{\left(\frac{A_s}{A_c} - N\right)} \tag{17}$$

and $$J = \frac{\mu_0 \, g_x \, e_y}{g_y\left(\frac{A_s}{A_c} - N\right)} \tag{18}$$

Where

$$\frac{1}{G_0} = g_x g_1 n \mu_0 A_c \tag{19}$$

Equations (17) and (18) define the magnetic quantities H and J in terms of electrical signals e_x and e_y respectively.

METHOD

When an empty pickup coil is placed in the solenoid field, the signal e_2 will only be due to the flux linking with coil area. In this case J = 0, $\alpha = 1$, N = 0 so that $H = H_a$ and Eqs. (13) and (16) yield

$$e_y = 0 \quad \text{and} \quad e_x = G_0^{-1} H_a \tag{20}$$

i.e. on CRO it will be only a horizontal straight line representing the magnetic field H_a. This situation will, obviously, be obtained only when the condition for (13) is satisfied.

Thus without a sample in the pickup coil a good horizontal straight line is a proof of complete cancellation of signals at the input of the Y-amplifier. This can be achieved by adjusting the gain of the integrator and also the phase with the help of network meant for this purpose. From known values of H_a and the corresponding magnitude of e_x, we can determine G_0 and hence calibrate the instrument. The dimensions of a given sample define the values of demagnetisation factor and the area ratio pertaining to the pickup coil. The demagnetisation factor can be obtained from the Appendix. These values are adjusted with the value of 10 turn helipots provided for this purpose. The value of the area ratio can be adjusted upto three decimal places whereas that of N upto four (Zero to 0.1 max.). The sample is now placed in the pickup coil. The plots of J, $\frac{dJ}{dt}$ and $\frac{d^2J}{dt^2}$ against H can be studied by putting the selector switch at appropriate positions. The graph of these quantities can also be obtained from time base by using the internal time base of CRO.

Since eddy currents are present in conducting ferromagnetic materials, the resulting J-H loop has a small loop in the saturation portion due to difference in phases for the forward paths. Moreover, these plots do not show horizontal lines at saturation and hence their shapes can't be employed as a criterion to adjust the values of demagnetisation factor.

The values of loop width, intercept on the J-axis and saturation position are determined in terms of volts for different applied fields. Plots of these against magnetic field are then used to extract the value of coercivity, retentivity and saturation magnetic polarization. The first corresponds to the intercept of the width against currents straight line on the Y-axis and it is essentially the measure of the width under no shielding effects. On the other hand, the remaining two parameters are derived from asymptotic extensions of the corresponding plots because these refer to the situation when shielding effects are insignificant. Caution is necessary in making the straight line fit for loop widths as a function of current data as the points for small values of magnetic current have some what lower magnitudes.

This is due to the fact that incomplete saturation produces lower coercivity values in the material. The geometrically obtained values of potentials are, in turn, used to find the corresponding magnetic parameters through equations (17) and (18).

If the area ratio for a particular sample is so small that the loop does not exhibit observable width, the signal e_x can be enhanced by multiplying α and β by a suitable factor and adjusting the two helipots accordingly. The ultimate value of the intercept can be normalised by the same factor to give the correct value of coercivity.

Calibration

Settings : Without sample. Oscilloscope at D.C. Time base EXT. H Bal., Phase and DC Bal. adjusted for horizontal straight line in the centre. Demagnetisation at zero and Area ratio 0.40. At Magnetic field 200gauss (rms)

e_x = 64mm, or

= 7.0V (if read by applying on Y input of CRO)

For Area ratio 1

e_x = 160mm,

or = 17.5V

From Eq. (20)

$$G_0(\text{rms}) = \frac{200}{160} = 1.25\text{gauss/mm}$$

$$G_0(\text{peak to peak}) = 1.25 \times 2.82$$

$$= 3.53\text{gauss/mm,}$$

also

$$G_0(\text{rms}) = \frac{200}{17.5} = 11.43 \text{ gauss/volt}$$

$$G_0(\text{peak to peak}) = 11.43\text{x}2.82$$

$$= 32.23\text{gauss/volt}$$

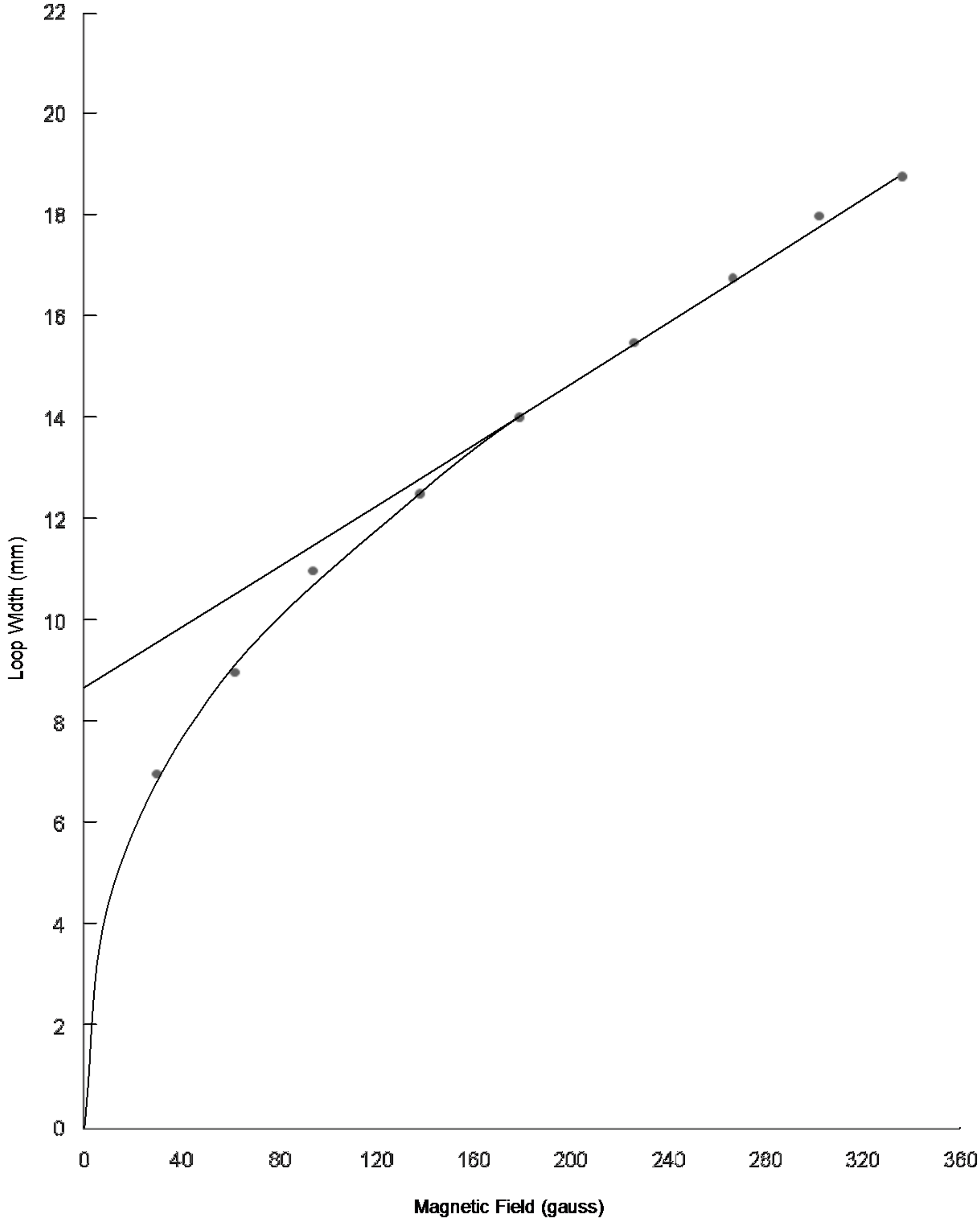


Fig. 4 : Dependence of Loop Width on Magnetic Field. The Intercept of Straight Line fit gives Coercitivity from equation

OBSERVATIONS

For this equipment diameter of pickup coil = 3.21mm

g_x = 100

g_y = 1

Sample : Commercial Nickel

Length of sample : 39 mm

Diameter of sample : 1.17 mm

Therefore,

Area ratio $\left(\frac{A_s}{A_c}\right)$ = 0.133

Demagnetisation factor (N) = 0.0029 (Appendix)

By adjusting N and $\frac{A_s}{A_c}$ as given above the J-H loop width is too small. Thus both are adjusted to three times i.e. 0.399 and 0.0087 respectively.

(a) Coercivity

S.No.	Mag. Field (rms) (Gauss)	2xLoop width (mm)
1.	30	7.0
2.	62	9.0
3.	94	11.0
4.	138	12.5
5.	179	14.0
6.	226	15.5
7.	266	16.75
8.	302	18.0
9.	336	18.75

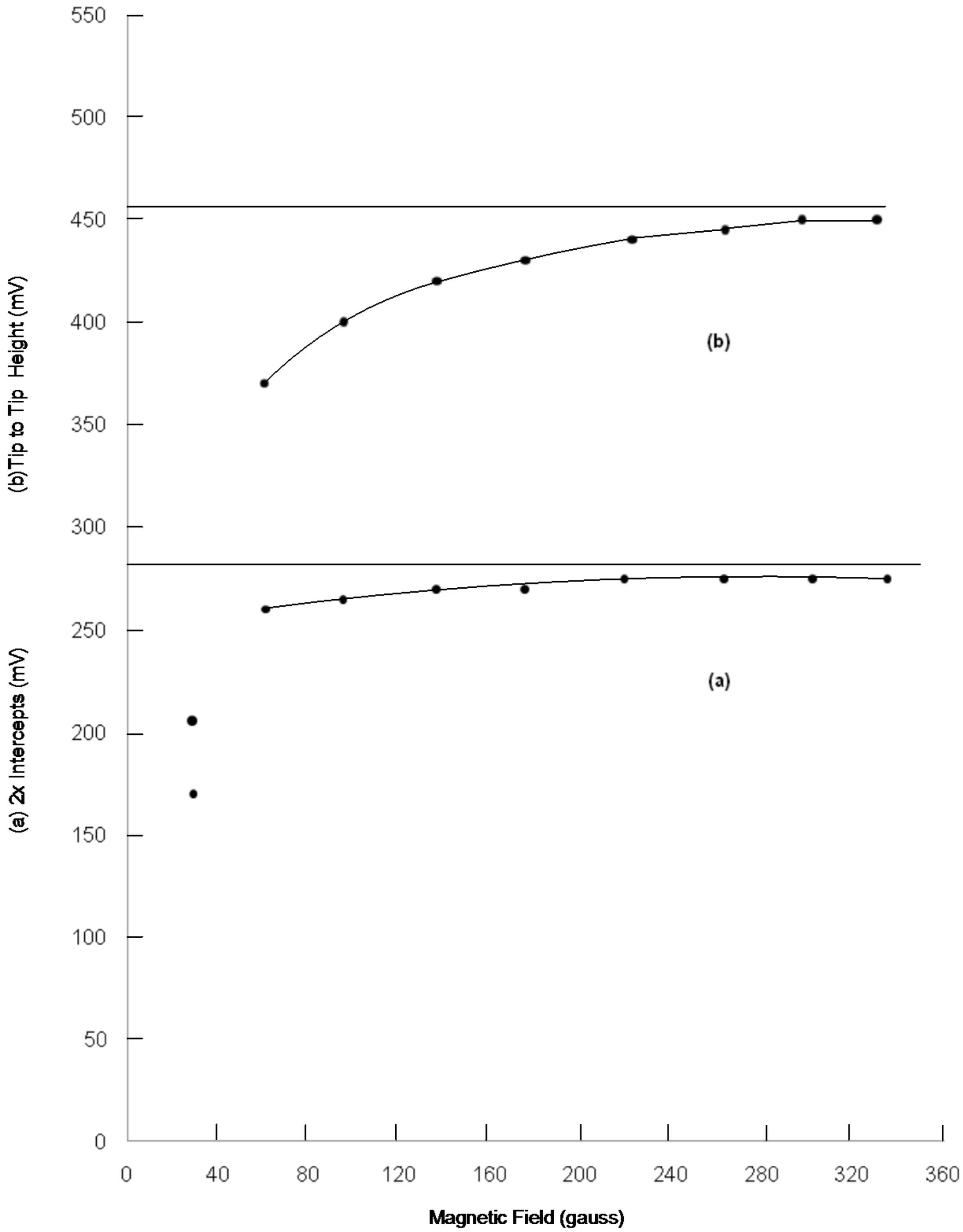


Fig. 5 Dependence of (a) Twice the intercept on the Y-axis, and (b) Tip to Tip Separation of J-H Plot for Commercial Nickel on Magnetic Field.

(b) Saturation magnetisation

S.No.	Mag. Field (rms) (Gauss)	Tip to tip height (mv)
1.	29	205
2.	61	370
3.	96	400
4.	137	420
5.	176	430
6.	223	440
7.	264	445
8.	298	450
9.	331	450

(c) Retentivity

S.No.	Mag. Field (rms) (Gauss)	2xIntercept (mV)
1.	29	170
2.	61	260
3.	95	265
4.	136	270
5.	175	270
6.	219	275
7.	263	275
8.	302	275
9.	335	275

From the graphs Fig. (4) and (5)

Loop width = 2.9mm (after dividing by the multiplying factor 3)
2xIntercept = 280mV
Tip to tip height = 457.5mV

CALCULATIONS

(a) Coercivity

Since e_x = ½ x loop width = ½ x 2.9 = 1.45 mm

$$H = \frac{G_0\, e_x}{\left(\frac{A_s}{A_c} - N\right)} = \frac{3.53 \times 1.45}{(0.133 - 0.0029)} = 39.3\text{Oe} \quad \text{from equation (17)}$$

(b) Saturation magnetisation

$$\mu_s = \frac{J_s}{4\pi} \qquad \text{due to equation (2)}$$

$(e_y)_s$ = ½ x tip to tip height = 457.5/2 = 228.75mV

$$\mu_s = \frac{J_s}{4\pi} = \frac{G_0\, \mu_0\, g_x\, (e_y)_s}{g_y \left(\frac{A_s}{A_c} - N\right) \times 4\pi} \qquad \text{from equation (18)}$$

$$= \frac{32.23 \times 1 \times 100 \times 0.229}{1 \times (0.133 - 0.0029) \times 12.56} = 452 \text{ gauss}$$

(c) Retentivity

$$\mu_r = \frac{J_r}{4\pi} \qquad \text{due to equation (2)}$$

$(e_y)_r$ = ½ x (2xIntercept) = ½ x 280= 140mV

$$\mu_r = \frac{J_r}{4\pi} = \frac{G_0\, \mu_0\, g_x\, (e_y)_r}{g_y \left(\frac{A_s}{A_c} - N\right) \times 4\pi} = \frac{32.23 \times 1 \times 100 \times 0.140}{1 \times (0.133 - 0.0029) \times 12.56} = 276\text{gauss}$$

Note : The above observation and calculation are given as a typical example. Test results of individual unit are supplied with the unit separately

QUESTIONS

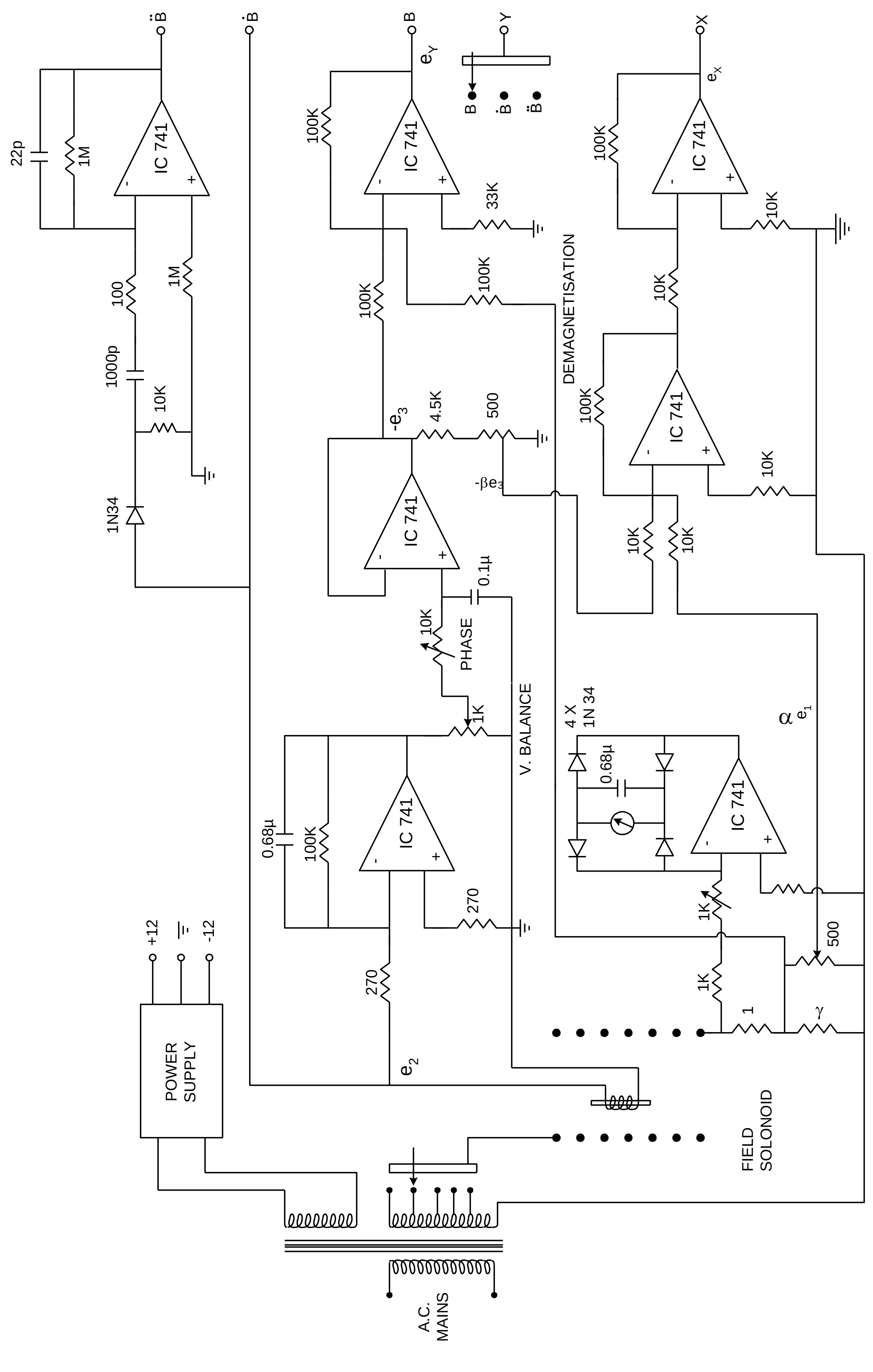
1. Explain the difference in J-H loop of hard and soft iron samples?
2. Why the loop width graph was extrapolated to zero magnetic field?
3. Why the asymptotes were drawn for finding J_s and J_r?

APPENDIX

Demagnetizing Factors for Ellipsoids of Revolution For prolate spheroids, c is the polar axis

C/a	$N_c/4$	C/a	$N_c/4$	C/a	$N_c/4$
1.0	0.333 333	4.0	0.075 407	20	0.006 749
1.1	308 285	4.1	72 990	21	6 230
1.2	286 128	4.2	70 693	22	5 771
1.3	266 420	4.3	68 509	23	5 363
1.4	248 803	4.4	66 431	24	4 998
1.5	0.232 981	4.5	0.064 450	25	0.004 671
1.6	218 713	4.6	62 562	30	3 444
1.7	205 794	4.7	60 760	35	2 655
1.8	194 056	4.8	59 039	40	2 116
1.9	183 353	4.9	57 394	45	1 730
2.0	0.173 564	5.0	0.050 821	50	0.001 443
2.1	164 585	5.5	48 890	60	1 053
2.2	156 326	6.0	43 230	70	0 805
2.3	148 710	6.5	38 541	80	0 637
2.4	141 669	7.0	34 609	90	0 518
2.5	0.135 146	7.5	0.031 275	100	0.000 430
2.6	129 090	8.0	28 421	110	363
2.7	123 455	8.5	25 958	120	311
2.8	118 203	9.0	23 816	130	270
2.9	113 298	9.5	21 939	140	236
3.0	0.108 709	10	0.020 286	150	0.000 209
3.1	104 410	11	17 515	200	125
3.2	100 376	12	15 297	250	083
3.3	096 584	13	13 490	300	060
3.4	093 015	14	11 997	350	045
3.5	0.089 651	15	0.010 749	400	0.000 036
3.6	86 477	16	09 692	500	24
3.7	83 478	17	08 790	600	17
3.8	80 641	18	08 013	700	13
3.9	77 954	19	07 339	800	10

From 'Introduction to Magnetic Materials' by B.D. Cullity (Addison - Wesley Pub. Co.)1972.



Schematic Diagram of Hysteresis Loop Tracer, HLT-111

TECHNICAL SUPPORT

Feed Back

If you have any comments or suggestions about this product or this manual please let us know. **SES Instruments Pvt. Ltd.** appreciates any customer feedback. Your input helps us evaluate and improve our product.

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Contacting for Technical Support

Before you call the SES Instruments Pvt. Ltd. Technical Support staff it would be helpful to prepare the following information:

- If you problem is with the SES Instruments Pvt. Ltd apparatus, note :
  - Model number and S. No (usually listed on the label at the backside of instrument).
  - Approximate age of the apparatus.
  - A detailed description of the problem/ sequences of events may please be sent by email or Fax.
- If your problem relates to the instruction manual, note;
  Model number and Revision (listed by month and year on the front cover).
  Have the manual at hand to discuss your questions.