GOVERNMENT OF PAKISTAN
MINISTRY OF COMMUNICATIONS
NATIONAL TRANSPORT RESEARCH CENTRE

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Manual For

Calibration of Laboratory Equipment

NTRC No. 206

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Contents

EXECUTIVE SUMMARY

Accurate measurement of Length, Mass and Temperature in any material testing laboratory is of extreme importance. It is always a necessary and good laboratory practice to calibrate the equipment commonly used for the measurement of these quantities, from time to time and to ensure that calibration data is readily available for reference when tests are being carried out for proper analytical work.

This Manual has been prepared for explaining the routine calibration procedures for the equipment, such as Balances, Ovens, and Dial Gauges, commonly used in any material testing laboratory. For ease of comprehension, the method for recording and maintaining calibration data, as adopted in NTRC laboratories, has also been illustrated in the Manual. References are made wherever possible to the British Standards BS:1377:1975, US Standards ASTM:1990 and various other publications and are gratefully acknowledged.

It is hoped that the Manual would be utilized as a working Manual by people involved in the handling of laboratories related to Highways and Civil Engineering. Comments if any, would be welcome.

Chapter 1
INTRODUCTION

The care of instruments employed in the laboratory is of utmost importance. Length, Mass and Temperature measuring instruments are precision made, should be treated with respect and protected against damage, dirt, dust and damp. They should be placed and stored in a clean and dry place.

1.1 CALIBRATION OF INSTRUMENTS

The performance of instruments like Weighing machines, Thermometers and Ovens, change over a period of time, and can vary with changes of temperature and other environmental conditions. Therefore, it is a good laboratory practice to calibrate them from time to time and to ensure that the latest calibration data are readily available for reference when tests are being carried out and result analyzed., in order to maintain a high standard of accuracy in results.

Table-1 shows the typical duration for which calibration is needed for a particular type of instrument.. Many other instruments are used with a manufacturers calibration certificate like Compressive Strength testing machine or CBR machine, which states the reading obtained at each of a series of intervals of the characteristic being measured. These values can be used as the basis of a calibration curve and should be readily available.

Table-1. Typical calibration periods.

Instrument	Period (Yrs)
Load Rings and Columns	2
Micrometers and Vernier calipers	1
Weighing Balances	1
Dial gauges	1
Thermometers	2
Ovens	1

Chapter 2
OBJECTIVE & SCOPE

It is always necessary in a good laboratory practice to calibrate laboratory equipment routinely, and ensure that the calibration data are readily available for reference when tests are being carried out and results analyzed.

2.1 OBJECTIVE

Due to the importance of the calibration processes for Mass, Length and Temperature measuring equipment used in materials laboratories, this guide is intended primarily as a working manual for people involved in maintaining the laboratories related to Highways and Civil Engineering.

2.2 SCOPE OF THE GUIDE

This manual is concerned with the routine calibration procedures of the equipment such as Weighing Balance, Drying Ovens, Length measuring instruments etc. commonly used in a material testing laboratory. The laboratory may range from a large fully equipped establishment to a small rudimentary testing center set up on the site of a project. Since it is intended as a working manual, it is addressed to those who are responsible for maintaining a laboratory.

2.2.1 PROCEDURES COVERED: This guide deals with standard procedures for the calibration of the equipment used for routine testing in a material laboratory and references are made wherever possible to British standards 1377:1975 and American Association of Testing Materials(ASTM). 1990. Also the method for recording and maintaining the calibration records of the equipments is described in the guide by demonstrating the comprehensive in-house calibration program of the equipments in use, in the laboratories of NTRC.

Chapter 3
PROCEDURE & INSTRUCTIONS

Major equipments which are frequently used in any material testing laboratory are Mass Weighing, Drying, Sieving and Temperature measuring equipments. The performance of main instruments changes over a period of time, and can vary with changes of temperature and other environmental conditions. Therefore, it is a good laboratory practice to calibrate and to ensure that the latest calibration data are readily available for reference.

3.1 WEIGHING

Mass can be measured to a greater degree of accuracy than can any other physical quantity in normal laboratory work, therefore weighing is always a very important activity in any material testing laboratory. Balances form an integral part of most laboratory tests methods. Several different types of balances are available in NTRC laboratories for accurate weighing, over the range from a fraction of a gram upto 25 kg. Maintenance and routine calibration of these balances is an essential part of regular working of material testing laboratories.

3.1.1 ELECTRONIC BALANCES: Electronic balances are the basic requirement for a modern laboratory where there is a requirement for high accuracy and throughput. They are reliable and have been designed to work under varied environmental conditions. Three different types of electronic balances are under use in NTRC laboratories. Their specifications and calibration procedure is defined in following paras:

3.1.1.1 ANALYTICAL & PRECISION TOP-LOADING BALANCE: (Oertling NA 264):

It is a simple to operate analytical and precision top-loading balance with weighing range from 0.1 mg to 260 gms and with a resolution of 0.0001g. Fig- 3.1.1.1 shows the balance, while Table- 3.1.1.1 represent the specification of the balance.

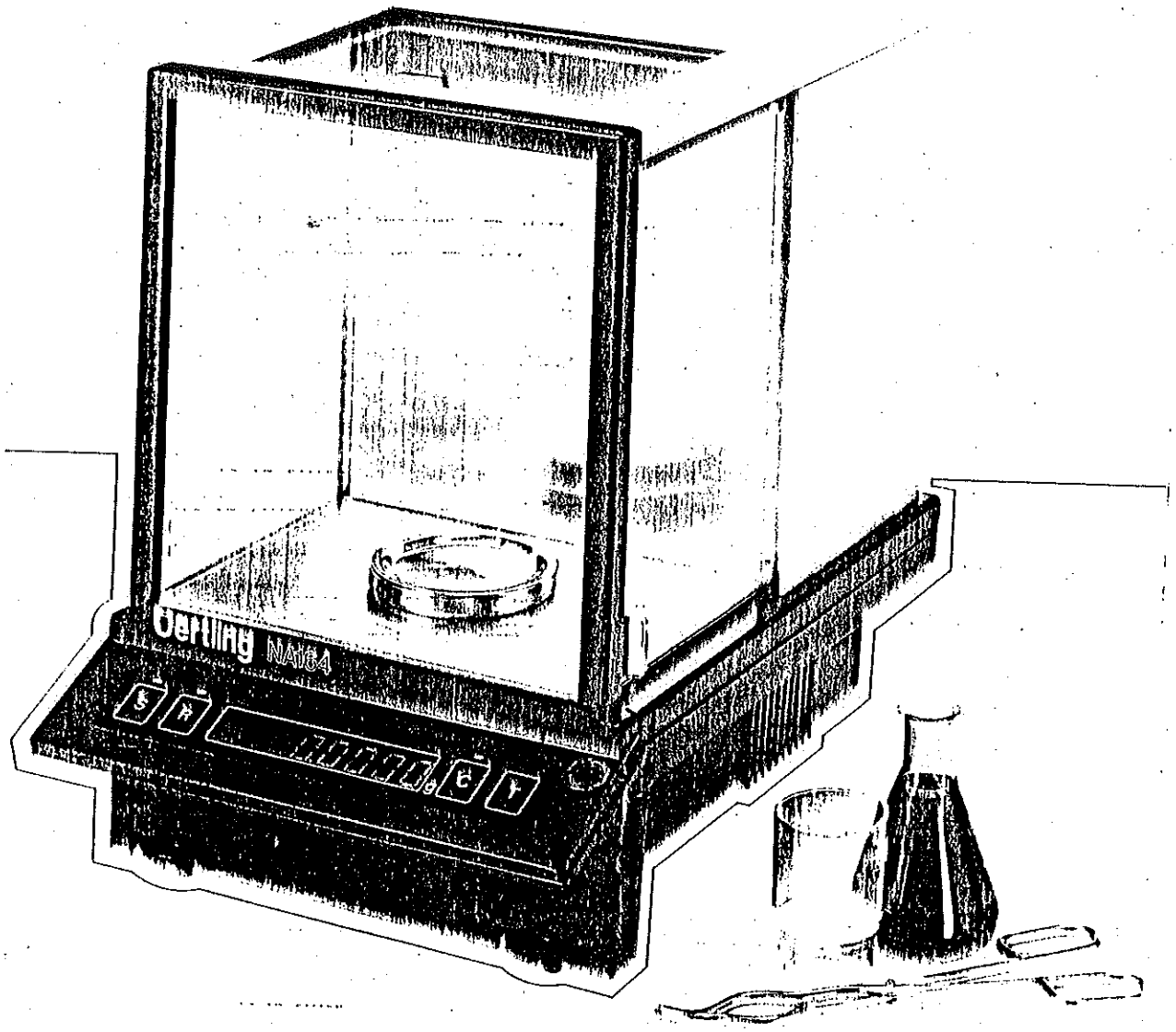


Fig- 3.1.1.1 Analytical & Precision Electronic Balance

Table- 3.1.1.1 Specifications of Oertling NA264

S.No	Specification	Oertling NA264
1	Capacity	260 g.
2	Readability	0.0001 g.
3	Reproducibility	0.0001 g.
4	Tare capacity	260 g.
5	Stabilization time	2.5 seconds.

3.1.1.1-A. CALIBRATION: Calibration of the balance is needed at the time of installation and then at regular intervals. Re-calibration is also desirable if the balance is used in different locations or under widely different temperature conditions.

3.1.1.1-B. PROCEDURE: With no load on the pan, close all windows and operate key " C" twice in quick succession. The display will show " cal " for a period of time, then revert to displaying zero. During this time an internal weight is automatically placed on the weighing mechanism and a calibration carried out [1].

3.1.1.2 **GENERAL TOP PANS BALANCE (Oertling OB 152):** It is a general purpose top pan electronic balance with weighing range from 1 g to 1500 gms. Fig-3.1.1.2 shows the balance while Table-3.1.1.2 presents its specifications.

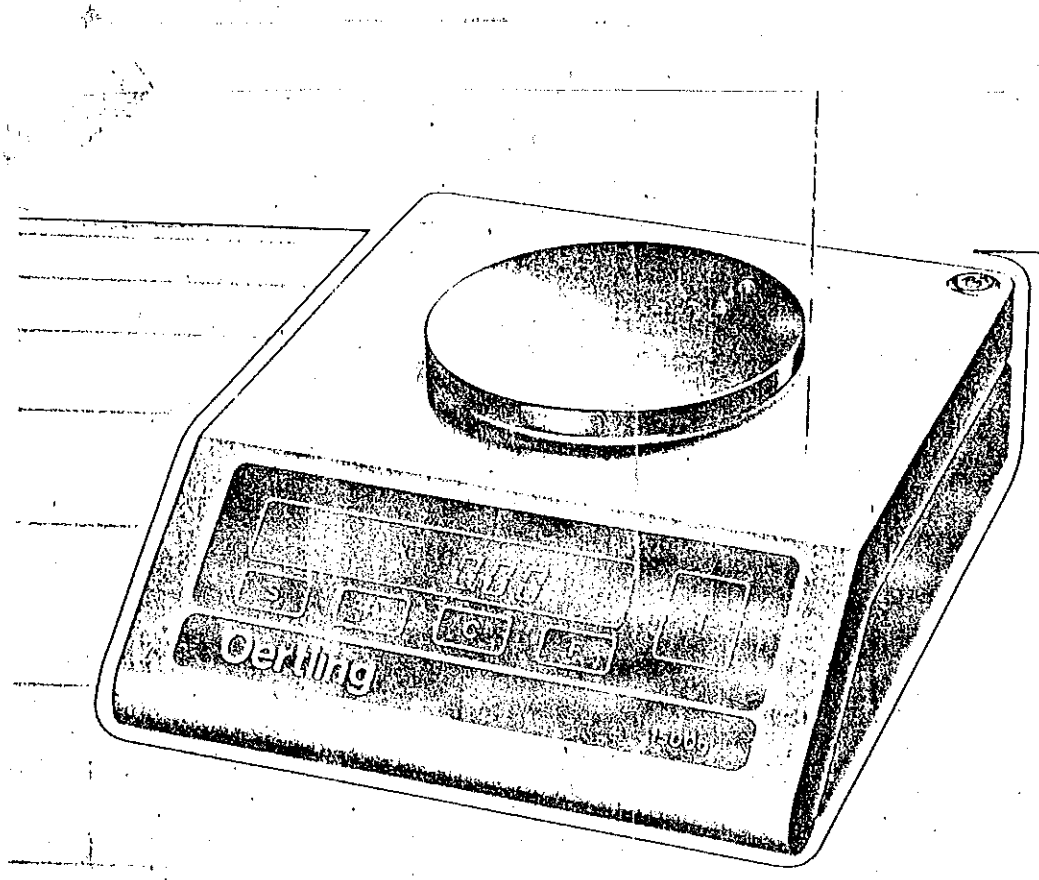


Fig- 3.1.1.2 A view of general top pan balance.

Table- 3.1.1.2 Specifications of Oertling (OB 152)

S.No	Specification	Oertling OB 152
1	Capacity	1500 gms.
2	Readability	0.01 g.
3	Reproducibility	0.01 g.
4	Tare capacity	1500 g.
5	Stabilisation time	1.5 seconds.

3.1.1.2-A. CALIBRATION: Calibration of the balance is needed at the time of installation and then at regular intervals.

3.1.2-B. PROCEDURE: The calibration of the balance is adjusted by recovers of potentiometer which is accessible through a hole on the right hand side face of the balance.

(a) Remove the plastic plug from this adjustment open time and start the balance and allow the balance to warm up. Check that the weight display is showing zero and if necessary press the T key to achieve this.
(b) Place a known calibration weight on to the pan (the calibration weight should resembles as close as possible the maximum capacity of the balance) and using small drives through the adjustment aperture, engage the potentiometer and time.
(c) As the potentiometer is turned the display will change. Take a note of the difference the actual weight and the displayed weight, this difference should be halved by turning the potentiometer remove the weight, re-zero the balance and steps each time reducing the errors while the actual and displayed weight are same. [2].

3.1.1.3 HIGH CAPACITY TOP PAN BALANCES: (Oertling SC 161): It is a high specification laboratory balance, similar in style to the precision range; provides high resolution combined with 16000 g capacity powered by a single-chip micro computer specifically designed for weighing applications, this balance adopts optimally to ambient temperature condition. Fig-3.1.1.3 shows the balance while Table-3.1.1.3 presents its specifications.

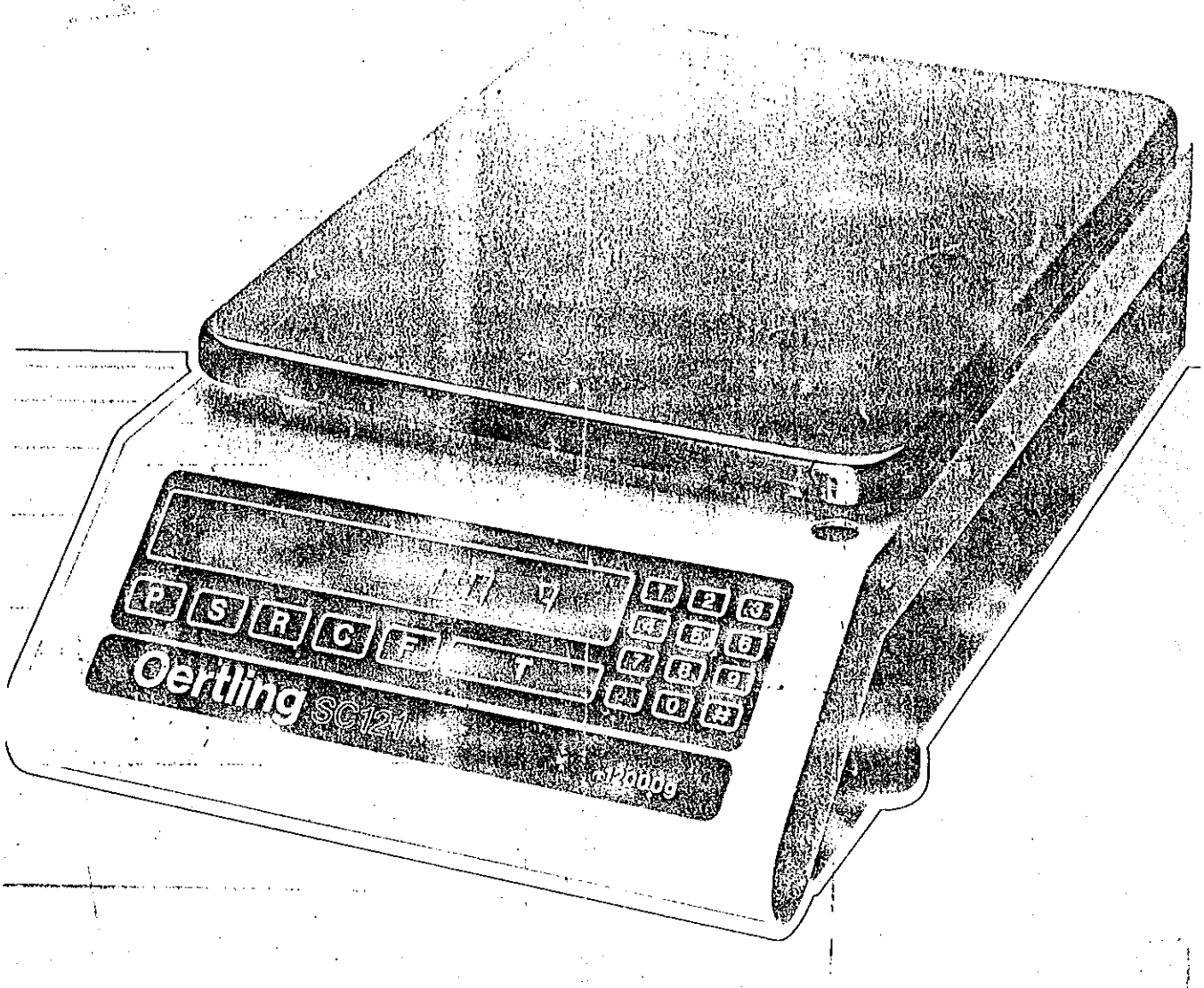


Fig- 3.1.1.3 The balance Oertling SC161

Table- 3.1.1.3 specification of high capacity top pan balance (Oertling SC 161)

S.No	Specification	Oertling SC161
1	Capacity	16000 g.
2	Readability	1 g.
3	Reproducibility	1 g.
4	Tare capacity	16000 g.
5	Stabilisation time	1.5 seconds.

3.1.1.3-A. CALIBRATION: Calibration of the balance is needed at the time of installation and then at regular intervals.

3.1.1.3-B PROCEDURE: To calibrate the balance the following steps should be taken.

a) Check there is nothing on the pen;

b) Press and hold down the "C" key until the segments of the display are illuminated release the "C" key then press again whilst all the segments and illuminated;

c) The word "Calibrating" is displayed whilst various checks are automatically carried out by the balance including reframening to a save controlled interval mass;

d) On completion of a successful calibration the balance will turn to zero, [3].

3.1.2 **SEMI-AUTOMATIC BALANCES** :The semi-automatic balance is designed to offer the user a robust balance which provides reliable and accurate results even under adverse conditions. The balance construction features a totally enclosed mechanism, engineered to operate with minimum maintenance. Fig.3.1.2 shows the balance while Table- 3.1.2 represents its features.

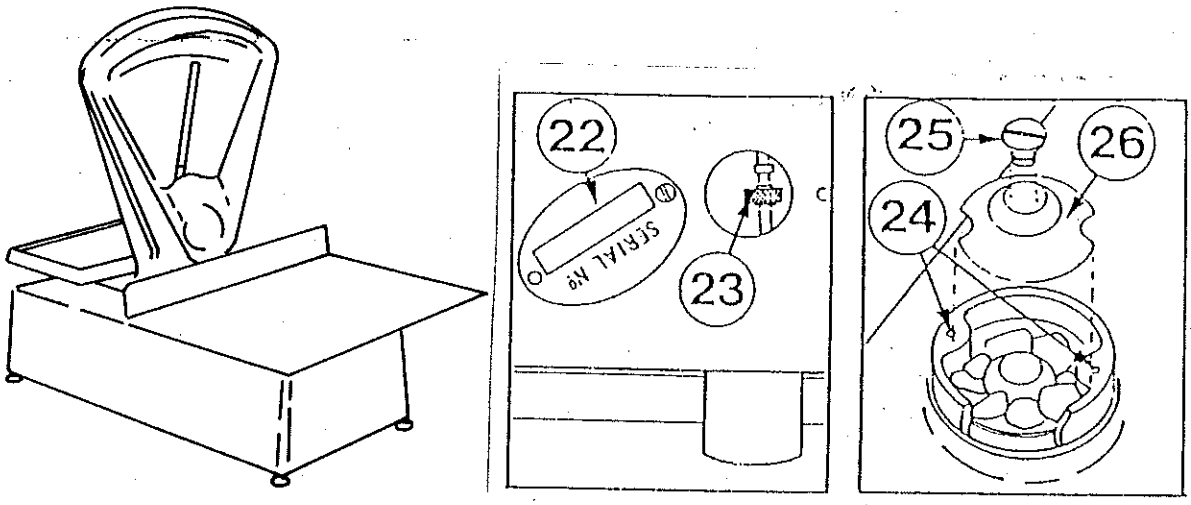


Fig- 3.1.2 A view of Semi-Automatic Balance

Table- 3.1.2 Specifications of Semi-Automatic Balance

Capacity of Balance	Scale (g)	Dimensions (l*w*h)	Weight(kg)
25 kg	200 * 1.0	515*570*310mm	36 kg

3.1.2.1 CALIBRATION: Calibration of the semi-automatic balances is needed at the time of installation and then at regular intervals.

3.1.2.2 PROCEDURE: Procedure for the calibration of such balances can be divided in to two main parts as follows:

a) CHECKING FOR ZERO READING: For dashpot adjustment, remove access cover(22) as marked in Fig. 3.1.2 and screw the knurled nut(23) up or down the stem. Correct damping is indicated when at half load the pointer swings once across and once back before settling. Check that the balance is indicating at zero load. If not, undo the screws(24) and (25) remove the cover (26) and locate the lead trimming weights (which are located in either front or rear pillar). Add or remove the lead weights to indicate zero load.

3.1.3 **CALIBRATION RECORD OF WEIGHING EQUIPMENT:** All the weighing equipment in use are calibrated as per standard procedure and recorded in Table-3.1.3 for future use.

Table-3.1.3 CALIBRATION RECORD OF WEIGHING EQUIPMENT

S.No	Date of Calib	Detail of Equipment	In-Service Since	Next Calb.on
1	21.1.97	Oertling NA 264	15-6-1992	21.1.98
2	22.1.97	Oertling OB 152	15-6-1992	22.1.98
3	23.1.97	Oertling SC 161	15-6-1992	23.1.98
4	24.1.97	Semi-Auto (No.1)	15-6-1992	24.1.98
5	25.1.97	Semi-Auto (No.2)	15-6-1992	25.1.98

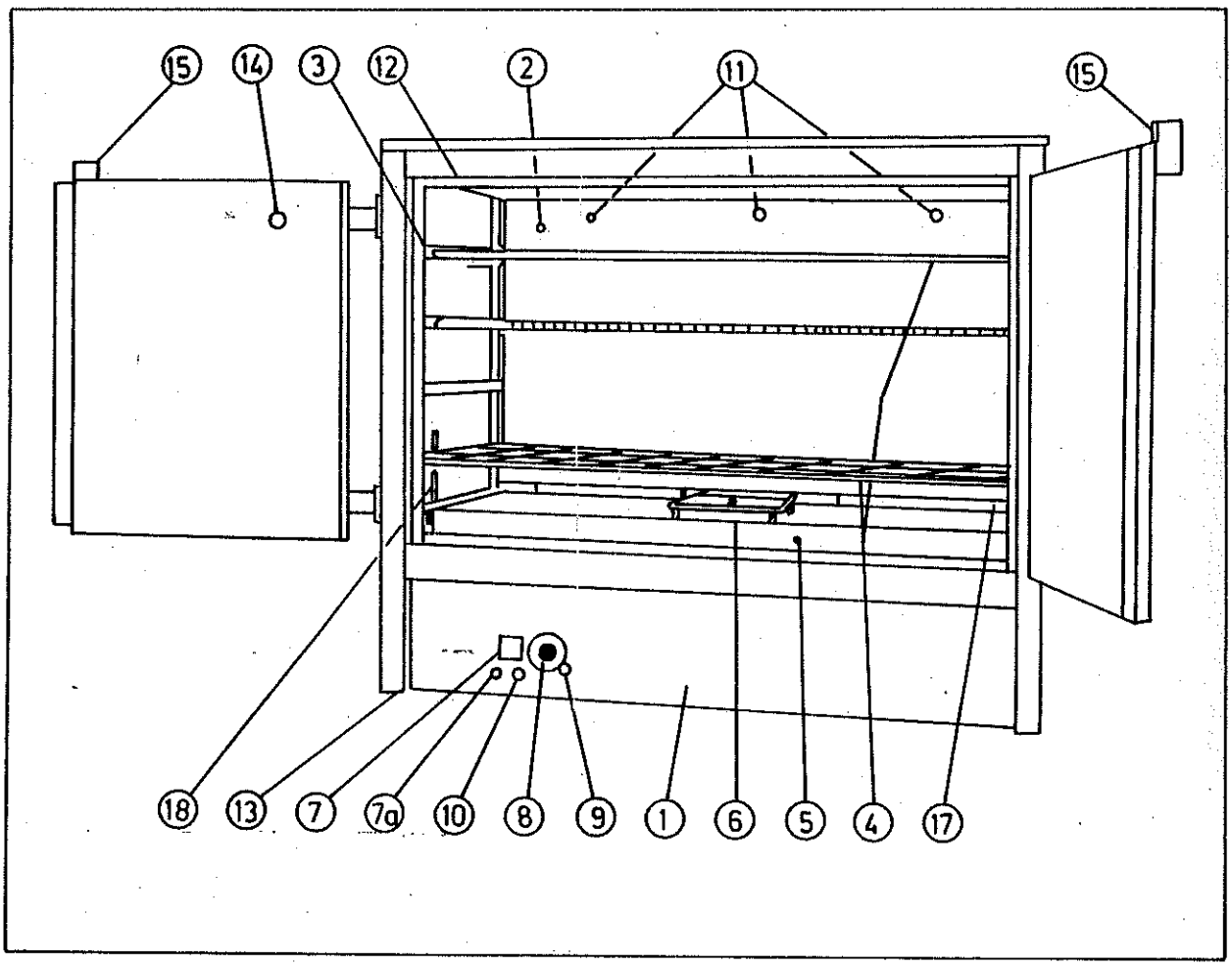
3.2 DRYING EQUIPMENT

Laboratory drying ovens provide a convenient means of material drying by heating to a predetermined and controlled temperature. Ovens are calibrated by setting the thermostat to a certain mark and recording the temperature indicated by a thermometer, when the temperature becomes steady. This is repeated for each major calibration mark on the scale and a temperature-calibration mark curve for each oven shall be plotted. It is important to calibrate the oven in the surroundings in which it is to be used. Different types of ovens are available in NTRC laboratories. Their specifications and calibration requirement are described in the following paras:

3.2.1 **SOIL DRYING OVENS**: During the course of the examination and testing of soil for engineering purposes, the technician will require to dry considerable quantities of soil. The temperature control for this is not critical but it is important that it should not be allowed to rise more then 10 ^{o} C above the boiling point of water. This limitation is to prevent damage to any organic matter that may be present. The British standard BS-1377 calls for an oven controlled to a temperature within the range of 105-110 ^{o} C. Specification of the oven is placed at Table-3.2.1, while plat-3.2.1 shows the oven [5].

Table-3.2.1 Specification of Soil Drying Oven

External Dimensions	**910 * 1040 * 510 mm (h * w * d)**
Temperature Range	**Ambient +10 ^{o} C to 150 ^{o} C**
Temperature Fluctuation	**+/- 0.5 ^{o} C**
Heater Elements	**1800 Watt**
Motor	**10 Watt**
No. of shelves	**3**
Weight	**114 kg**



1. Outer Shell of oven - plastic coated steel.
2. Oven chamber - mild steel coated with aluminum
3. Shelf support frame for up to 3 shelves
4. 3 heavy duty wire mesh shelves
5. Aluminum coated mild steel false floor over heating elements
6. Cover over recalculation fan
7. Mains power on/off switch
8. Variable thermostat control graduated in unit degree
9. Thermostat lock
10. Heat on indicator neon
11. Three ventilation holes with access to rear of oven
12. Flexible copper seal along top edge of oven doors
13. Four feet
14. Access port for thermometer with external cover
15. Door catch mechanism
16. Thermostat sensor
17. False floor retain screws

Plate 3.2.1 General Arrangement of Soil Drying Oven

3.2.1.1 CALIBRATION PROCEDURE OF SOIL DRYING OVEN: In order to calibrate the thermostat of the oven. Calibration procedure is described in the following paras:

Measurement method:

1. It is recommended that the temperature control for the oven is checked using a temperature sensor placed in the centre of the oven which is empty except for shelving.

2. The preferred temperature sensor is a thermocouple with a suitable readout unit. The alternative is a total immersion thermometer. It is not recommended that the door fitted thermometer be used for this check.

Procedures:

1. With the oven set ready to run, slacken the temperature control clamp marked (24) in figure 3.2.1.1 and set the control to the expected required temperature.

2. Remove the control knob cover plate (23). Do not slacken the knob at this stage.

3. Switch on the oven and run until two consecutive readings over 15 minutes are the same. Do not make any adjustments to the control until the required operating temperature is attained.

4. To adjust the control the knob to indicate the correct temperature against the indicator(28), lock the friction clamp then slacken the control knob nut, ease the knob away from the shaft and unlock the clamp to allow the scale to be moved. Relock the clamp before tightening the control knob nut..

5. Lock the friction clamp(24) and check the operating temperature.

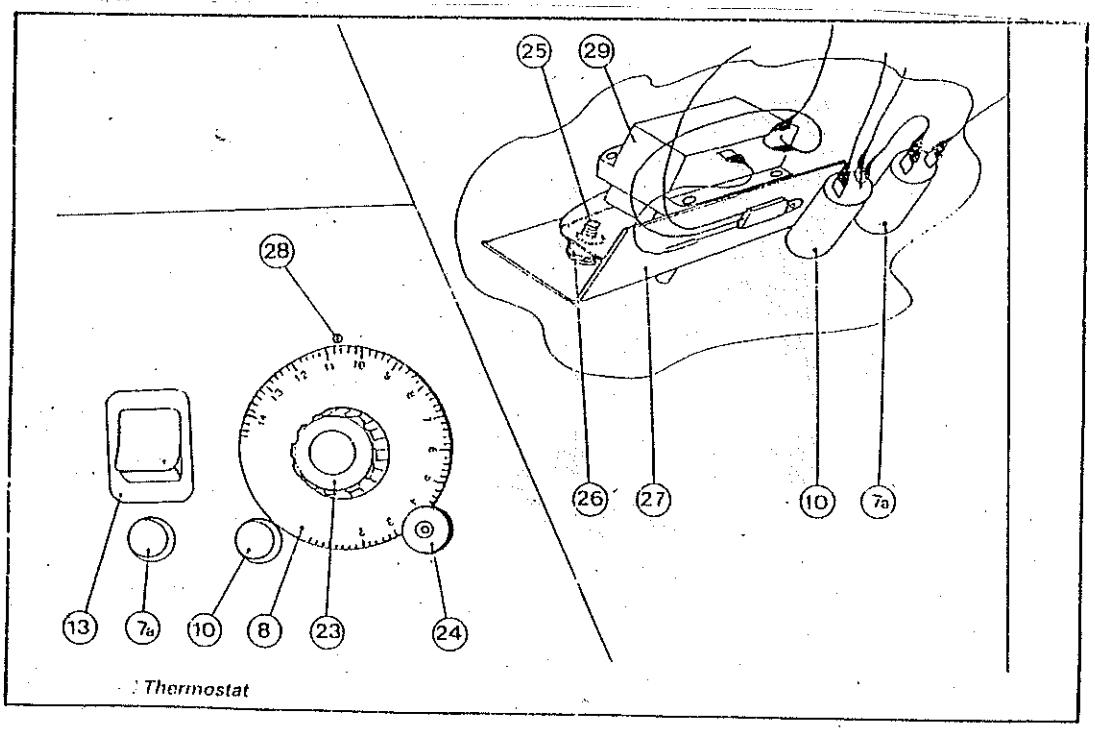


Fig.3.2.1.1 Thermostat Calibration of Soil Drying Oven.

3.2.2 **FAN–CIRCULATED OVEN:** These ovens have been designed to perform to requirements of British Standards BS-2648 and BS-3421. Arbitrary scaled controls for both the temperature control thermostat and the safety thermostat have simple locks to prevent accidental movement. Adjustable over the range of 50-300 ^{o} C, the control state is indicated by an amber lamp while the safety (overheated state) is indicated by a red lamp. Both lamps being positioned to be related to their respective knobs.

A range temperature switch is fitted, which in the "lo" position, switches out one element to obtain close control in the lower end of the range. Plate 3.2.2 shows the oven.

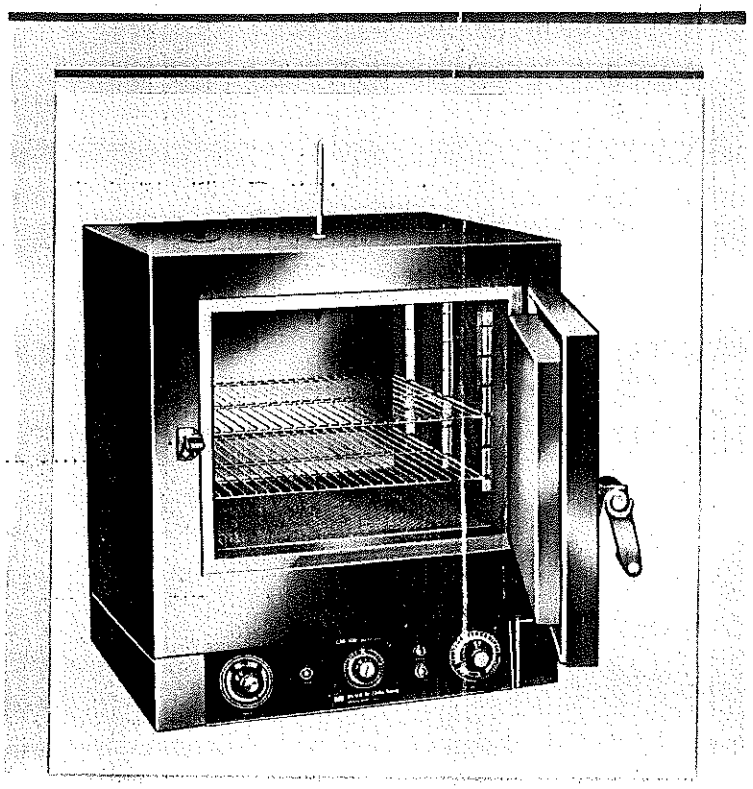


Plate 3..2.2 Fan Circulated 300 ° C Oven

3.2.2.1 **Calibration Procedure of the Fan Circulated Oven:** It is a general practice to calibrate the thermostat dial, that is not necessarily marked in ° C but may be only controlling mark. The oven is calibrated by setting the thermostat to a certain mark and recording the temperature indicated by a thermometer when the temperature becomes steady. This repeated for major controlling marks on the scale and a temperature-calibration graph as shown in Fig. 3.2.2.1 is plotted. It is important to calibrate the oven in the surroundings in which it is to used. If an oven is moved to a different place in the laboratory, a fresh calibration will be needed. A full oven may give a different calibration from an empty oven, so the calibration should be done with "average" contents in the oven.

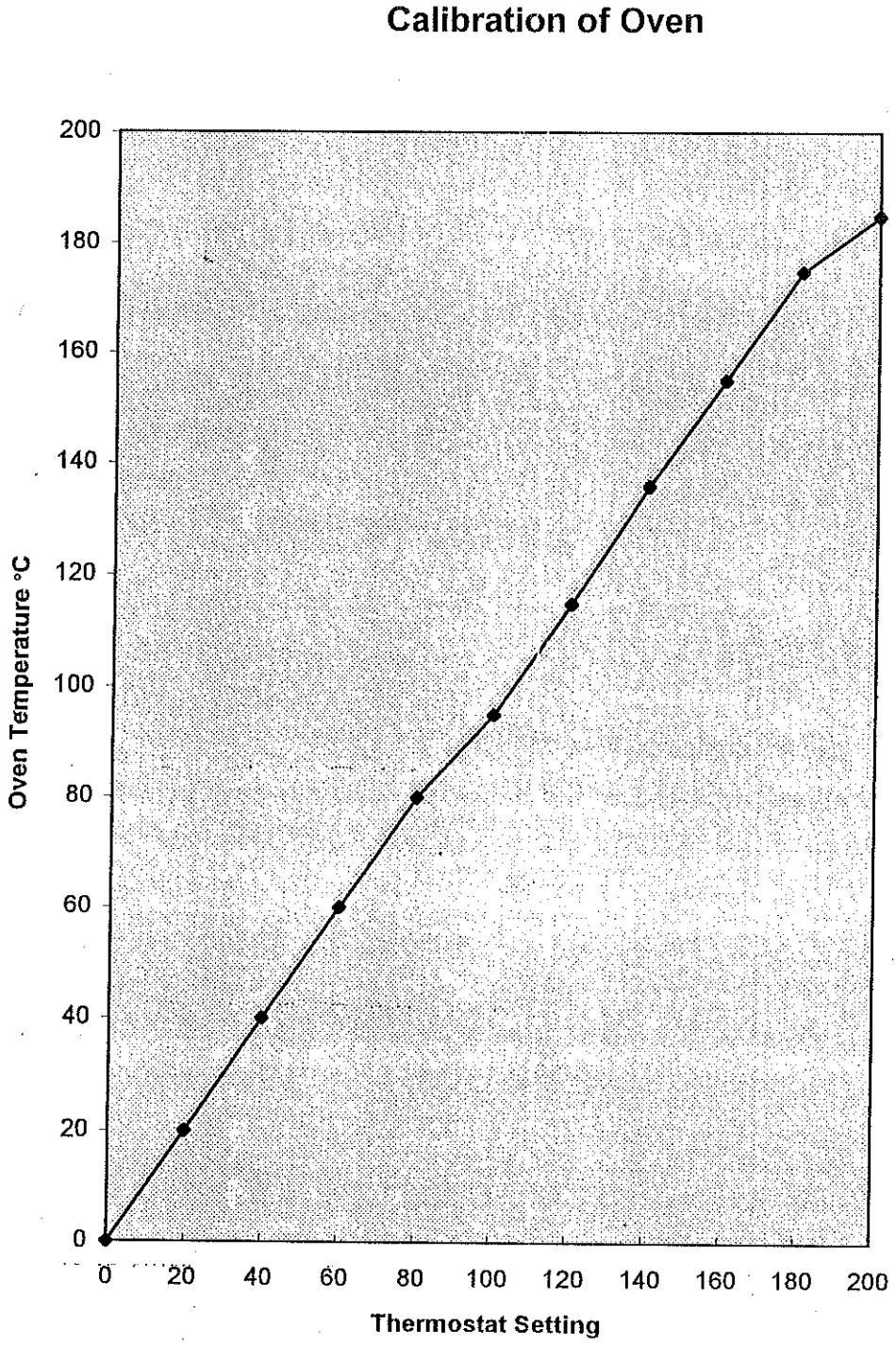


Fig. 3.2..2.1 A typical Temperature - Calibration Graph for Oven.

3.2.3 CALIBRATION RECORD OF DRYING EQUIPMENT: All ovens which are in use have been calibrated as per the standard procedure and their record is placed in Table-3.2.2 for future use.

Table- 3.2.2 CALIBRATION RECORD OF OVENS

S.No	Detail of Oven	In-Service Since	Date of Cal	Due Cal. On
1	Soil Drying Oven S.No 589HO70	15-6-1992	25-6-1997	25-6-1998
2	Fan Circulated S.No D5C89HO95	15-6-1992	26-6-1997	26-6-1998
3	Fan Circulated Oven 300 o C	15-6-1992	26-6-1997	26-6-1998

3.3 MEASUREMENT OF LENGTH

Measurement of length is always an important activity in materials testing and it is always demanding that length measuring equipment such as dial gauges, vernier calipers, steel rule etc, shall be in very good condition and with reliable results. For this purpose they should be calibrated from time to time in order to get reliable performance from them. Some common devices for length measurement are mentioned in Table-3.3 with their recommended specifications, while figure 3. 3 shows the equipment.

Table-3.3 INSTRUMENTS FOR MEASURING LENGTH

Instrument	Ref. Figure 3. 3	Range	Resolution (m m)
Pocket Tape	3.3 - a	2 m or 3 m	1.00
Meter Stick	3.3 - b	1 m	1.00
Steel Rule	3.3 - c	300 mm	0.05
Pocket Steel rule	3.3 - d	150 mm	0.50
Vernier Calipers	3.3 - e	150 mm	0.1
External Caliper	3.3 - f	150 mm	
Internal Caliper	3.3 - g	150 mm	
Micrometers	3.3 - h	25 mm	0.01
Dial Gauge	3.3 - j	15 mm	0.005
Dial Gauge	3.3 - k	50 mm	0.01

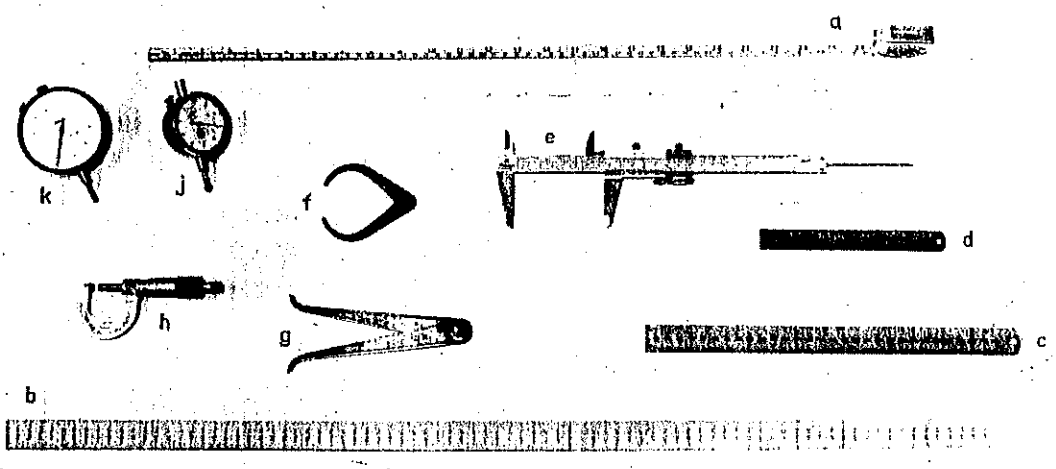


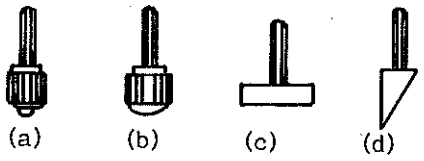
Fig - 3.3 Instruments For Measuring Length.

3.3.1 DIAL GAUGES: The device for the accurate measurement of length is the dial gauge, different types of dial gauges most commonly used in a soil laboratory are listed in Table 3.3.1. Useful accessories for dial gauge include extension stands and various types of anvil.

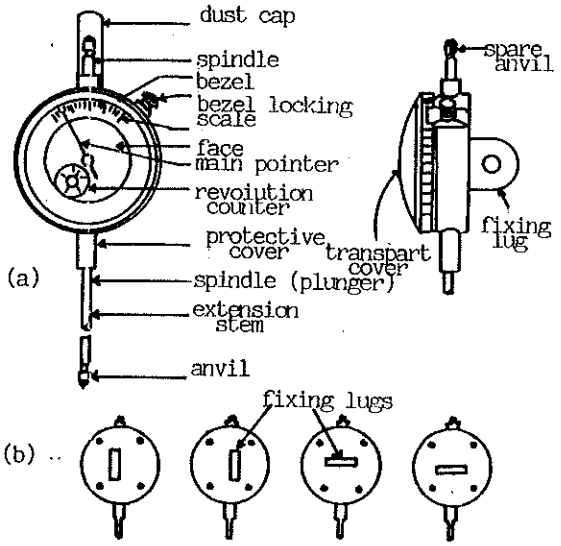
Table - 3.3.1 Dial Gauges For Linear Measurement

Ref. No.	Face Dia	Travel	Grad.(1 div)	Dial mark & Direc	Tra/Rav	Application
a	57 mm	5 mm	0.002 mm	0 - 100 (C)	0.2 mm	Load Rings
b	2.25 inch	0.25 mm	0.0005 inch	0 - 50 (C)	0.0025 in	CBR Penet.
c	2.25 inch	0.25 mm	0.001 inch	0 - 100 (C)	0.001 in	Socking

The dial gauge listed in table 3.3.1 are all the continuos reading type, i.e. the main points describe numerous revolutions during the full travel of the stem secondary pointer indicating the number of revolutions. Fig 3.3.1 shows different components of dial gauge.



Anvils for dial gauges:(a) standard-steel ball,(b) rounded(button), (c)flat, (d) chisel (offset)



Typical dial gauge details: (a) main features, (b) backplate with offset fixing lug in four positions

Fig.- 3.3.1 Typical Dial Gauges Details.

3.3.2 CALIBRATION OF DIAL GAUGES: Commercial dial gauges are manufactured to comply with specified tolerances of non-linearity (BS-907:1965) which are summarized in table 3.3.2. Readings may be verified by mounting the gauge in a bench stand on a flat surface and inserting engineers's slip gauges of accurately measured thickness under the anvil first setting the gauge to read zero.

Table- 3.3.2 Accuracy of Performance of Dial Gauges.

Interval of Reading	Limit of Error in reading over stated interval (mm)	Repeatibility of reading	Discrimination
Any 0.1 mm	0.005	Within 0.0002	Within 0.003
Any half revolution	0.0075	mm.	mm during
Any one revolution	0.01		gradual change
Any two revolution	0.015		of about 0.025
Any larger interval	0.020		mm .

3.3.3 CALIBRATION RECORD OF DIAL GAUGES: All the three types of dial gauges which are in use in the NTRC laboratories have been calibrated and the record is placed at Table 3.3.3 for ready reference.

Table - 3.3.3 Calibration Record Of Dial Gauges.

Ref. No	Face Dia	Travel	In-Service Since	Date Of Calibration	Due Date Calibration	Application
a	57 mm	5 mm	15-6-1992	10-6-1997	10-6-1998	Load Ring
b	2.25 in	0.25 in	15-6-1992	15-6-1997	15--6-1998	CBR Pent.
c	2.25 in	1.00 in	15-6-1992	18-6-1997	18-6-1998	Soacking

Chapter 4
CONCLUDING REMARKS

This manual describes the fundamentals as well as the practical applications related to the maintenance and calibration of general equipment used in any material testing laboratory. It is always a necessary and good laboratory practice to calibrate the equipment commonly used for the measurement of Length, Mass and Temperature, from time to time and to ensure that calibration data is readily available for reference when tests are being carried out for proper analytical work.

This Manual has been prepared for explaining the routine calibration procedures for the equipment, such as Balances, Ovens, and Dial Gauges, commonly used in any material testing laboratory. For ease of comprehension, the method for recording and maintaining calibration data, as adopted in NTRC laboratories, has also been illustrated in the Manual. References are made wherever possible to the British Standards BS:1377:1975, US Standards ASTM:1990 and various other publications and are gratefully acknowledged.

It is hoped that this manual will be utilized as working manual by people involved in the handling of laboratories related to Highways and Civil Engineering. Primarily, this manual is designed to refresh the knowledge of technical staff who have responsibilities to run material testing laboratories. However, efforts have been made to keep the text as simple as possible for the understanding of user except for few technical illustrations without which this manual would not have been comprehensive.

It will be highly appreciated if comments are offered for its further improvement.

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[2] Oertling "Electronic Top Pan Balance", Operating Instructions Manual, Avery Ltd. Smethwick Warly B662LP, England, April 1989.

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[5] ELE "Soil Drying Oven" EL-22-0110, Operating Instructions Manual, ELE Int. Ltd. Eastman Way, Hemel Hempstead Hertforshire, England, March 1990.

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