

ERRORS IN APPROXIMATION

A Special project report

by

SUDHEENDRA DHULKHED

Guide

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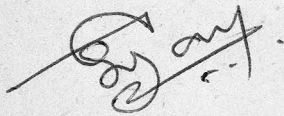
Indian Institute of Technology

Powai Bombay-400 076

March 1988

APPROVAL SHEET

*The special project titled "Errors in approximation" by Sudheendra Dhulkhed
is approved in partial fulfilment of the requirement for M.Des degree in
Industrial Design.*

A handwritten signature in dark ink, appearing to be 'Sudheendra Dhulkhed', written over a horizontal line.

Signature

Date June 14/1988

Guide

ACKNOWLEDGEMENT

*I, sincerely thank Dr. G. G. Ray for his
valuable guidance and encouragement
throughout this project.*

*I, also, sincerely thank all faculty
concerned and my friends for
their kind help extended during
this project.*

SUDHEENDRA DHULKHED

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1. INTRODUCTION

Measurement in many industrial and practical context is done by human judgement. For example, in a heat treatment unit, the colour of the slab is the variable for judging the hardness temperature reached, even though technology is available to measure the temperature accurately. (1) (2)

In industry and every day life it is necessary to measure some value through human approximation even though no technology is available for doing so.

Approximation is used for measurement of some variable even there is technology available for the purpose. For example in graphical and analogue displays, the value of some variable is represented by a length of a line without a scale besides it. Observer approximates the length of the line and estimates the value of the variable. Dial and pointer displays are often read by visually judging the angle of the pointer rather than accurately reading the scale mark, it indicates. This happens when rapid reading is necessary.

This also happens in case of some watches wherein only four discrete points are marked on the dial. (1) (2)

In some process control rooms dials and meters are located at a height. The operator has to visually judge and note readings, seeing the pointers only, as these meters will be at a height.

In designing such displays it is necessary to know the average deviation from the actual value or error in approximating the value of a variable, under a given condition. This value will help to allow the required amount of tolerance to be given in the machines so that accidents due to human errors can be prevented, in all remote sensing plants like nuclear power plants and process plants.

The aim of the current project is, *"To determine and study the deviation pattern from the actual value while approximating a variable visually"*.

2. FACTORS AFFECTING VISUAL APPROXIMATION

It is well known fact that, environmental conditions, conditons of the display and human being affect the accuracy of visual approximation.

Factors affecting the visual approximation are as listed below.

In case of the display

- a. Size of the display
- b. Shape of the display
- c. Size & shape of the elements in the display
- d. Orientation of the elements in the display
- e. Reference available
- f. Colour & contrast of the background and foreground
- g. Distance between the elements
- h. Distance between end elements and edges of the display

In case of environment

- a. Surrounding lighting (Illumination)
- b. Noise/vibration disturbances
- C. Dust & fumes

In case of observer

- a. Age
- b. Experiance
- c. Mental condition
- d. Time given for reading
- e. Distance between display & observer

3. *EXPERIMENTAL SET UP*

A slide projector is used for the task and the projection of predetermined shape and size becomes the display. (Refer Fig. 3.1)

The elements of the display are ten lines of different lengths, in different orientations, with a colour background.

I have taken the following factors affecting the visual approximation as constant and variable.

Constant factors

1. *Shape & size of the display*

A square of 150 cm.

2. *Width of the line*

1 cm.

3. *Colour of the line*

Black.

4. *Time*

6 Sec. per line. / 1min for Group.

5. *Surrounding lighting condition*

1.3 Lux.

6. *Noise*

Noise level, 59 db.

6. *Distance between observer & display*

200 cm.

7 *Visual Angle*

37

Variable factors

- | | |
|--------------------------------|----------------------|
| 1. <i>Length of line</i> | 10 values |
| 2. <i>Back ground Colour</i> | (a) white |
| | (b) Blue |
| | (c) Red |
| | (d) Yellow |
| 3. <i>Orientation of lines</i> | (a) Individual Lines |
| | (b) Group |
| | (1) Increasing Order |
| | (2) Random |

Subjects

- | | |
|----------------------|------------------------------------|
| 1. <i>Profession</i> | M. Tech. (Mechanical & Chemical) |
| 2. <i>Age group</i> | 25 - 27 yrs. |

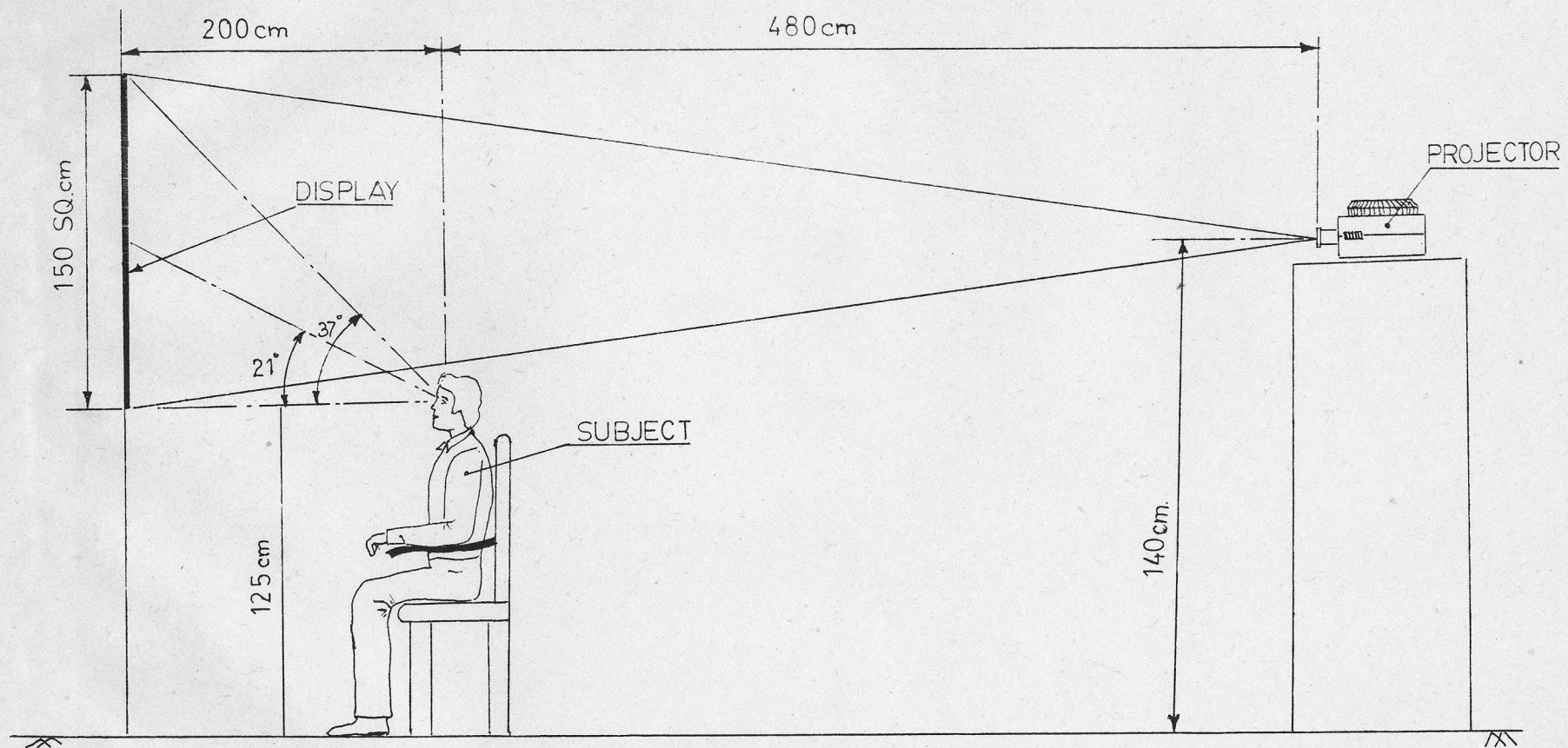


FIG. 3.1 EXPERIMENTAL SET UP

4. METHODOLOGY

The display contains a line or a group of lines with a colour back ground.
The projection done on a white wall.

The projection should be so adjusted that the size of the display is 150x150 cm.
and width of the line is 1 cm.

Observer sits on a chair kept at a distance of 200 cm. from the display.

Observer has to measure the length of the line visually in the prescribed time.
The value is noted.

A table of visually measured values of the lines, actual length and deviation
or error is made.

Test is repeated for different subjects.

Further statistical calculations are made. Results are plotted on the graphs.

Subjects are asked to tell the background colour. It is observed that all
subjects told the background colour correctly. Hence it was assumed
that subjects were not colour blind, without going through the
'Ishihara' test.

5. TABULATIONS & GRAPHS

Experiment is conducted on 20 subjects. The values approximated by them are grouped into two categories.

They are,

1. shorter length lines (1cm to 10cm)
2. longer length lines (25cm to 100cm)

The readings are tabulated in the following tables 1.1 to 6.2., followed by graphical representation of the mean % error and std. deviation v/s actual value.

TABLE 1.1

Actual length →	1 cm.			2 cm.			4 cm.			5 cm.			10 cm.		
Subject ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	1.2	-0.2	-20	2.1	-0.1	5	4	0	0	5	0	0	10	0	0
2	1	0	0	1.8	0.2	10	3.8	0.2	5	5	0	0	10	0	0
3	1.3	-0.3	-30	2.2	-0.2	-10	4.2	-0.2	-5	5	0	0	10	0	0
4	1.4	-0.4	-40	2	0	0	4.2	-0.2	-5	5.5	-0.5	-10	10	0	0
5	1	0	0	2	0	0	3.8	0.2	5	5.5	-0.5	-10	10	0	0
6	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
7	1	0	0	2.2	-0.2	-10	4	0	0	5	0	0	11	-1	-10
8	1	0	0	2	0	0	4	0	0	4	1	20	10	0	0
9	1	0	0	2	0	0	3.8	0.2	5	5	0	0	9	1	10
10	1	0	0	2	0	0	4	0	0	4.5	0.5	10	10	0	0
11	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
12	1	0	0	2.2	-0.2	-10	4.2	-0.2	-5	5	0	0	10	0	0
13	1.1	-0.1	-10	2	0	0	4	0	0	5	0	0	10	0	0
14	1	0	0	2	0	0	4	0	0	6	-1	-20	11	-1	-10
15	1	0	0	2	0	0	4.2	-0.2	-5	5	0	0	10	0	0
16	1	0	0	2.5	-0.5	-25	4	0	0	5	0	0	10	0	10
17	1.1	-0.1	-10	2	0	0	4	0	0	5	0	0	10	0	0
18	1	0	0	2.2	-0.2	-10	4	0	0	5	0	0	10	0	0
19	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
20	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
Mean % error	-5.4			-3			-0.25			-0.5			-0.5		
Std. deviation	±11			±7			±3			±6.8			±3.8		

Back Ground

White

error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orientation

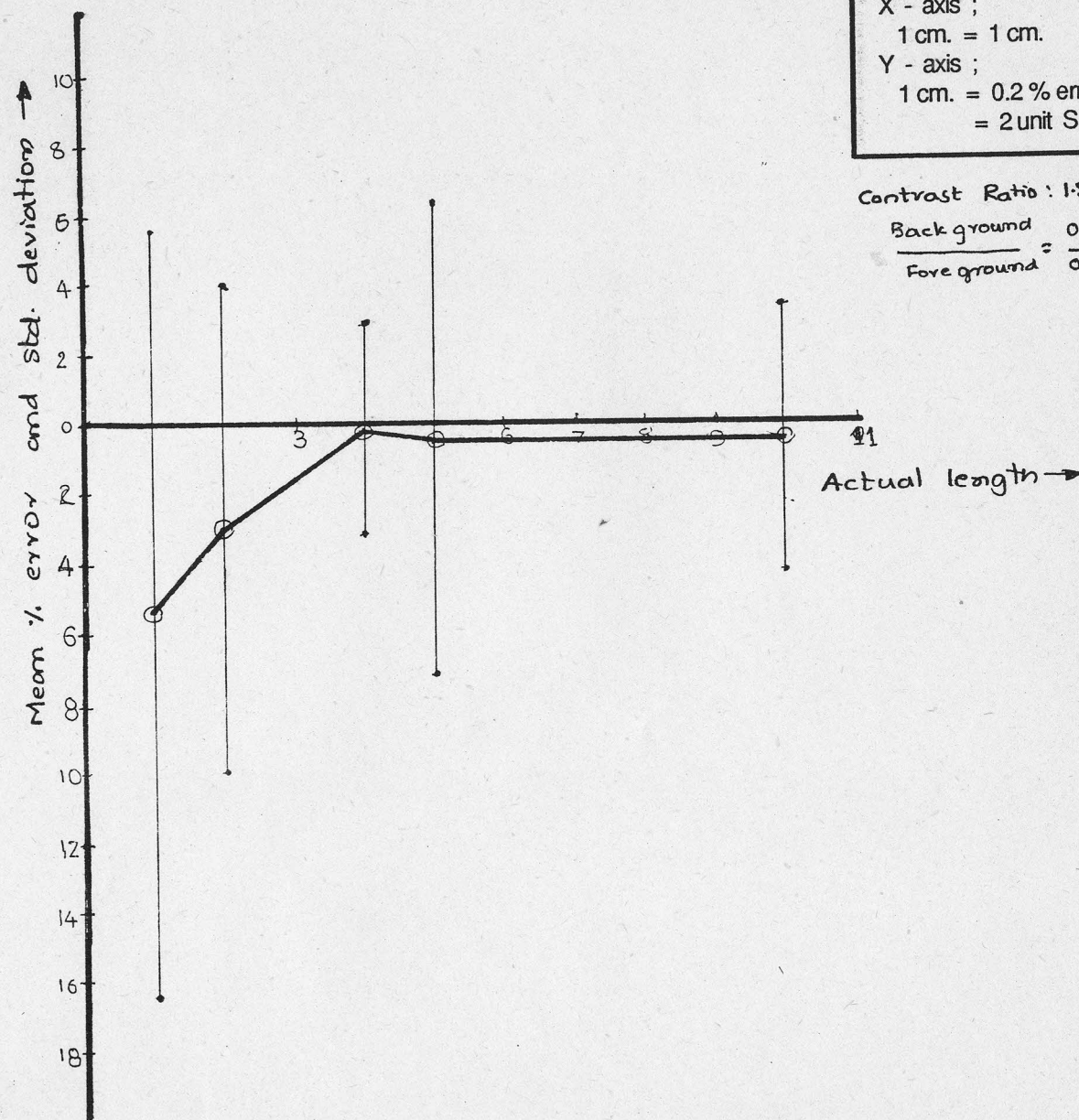
Individual
Vertical

I

SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio : 1.54:1

Back ground = 0.85
 Fore ground = 0.53



GRAPH OF %ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 1.1

TABLE 1.2

<i>Actual length</i> →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
<i>Subject</i> ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	30	-5	-20	40	0	0	50	0	0	70	5	6.7	90	10	10
2	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
3	25	0	0	40	0	0	50	0	0	80	-5	-6.7	90	10	10
4	20	5	20	30	10	25	40	10	20	70	5	6.7	80	20	20
5	20	5	20	35	5	12.5	45	5	10	75	0	0	95	5	5
6	20	5	20	40	0	0	50	0	0	75	0	0	100	0	0
7	25	0	0	50	-10	-25	60	-10	-20	80	-5	-6.7	100	0	0
8	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
9	20	5	20	35	5	12.5	40	10	20	60	15	20	90	10	10
10	20	5	20	40	0	0	45	5	10	70	5	6.7	90	10	10
11	25	0	0	30	10	25	50	0	0	75	0	0	100	0	0
12	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
13	30	-5	-20	40	0	0	50	0	0	80	-5	-6.7	100	0	0
14	30	-5	-20	40	0	0	60	-10	-20	80	-5	-6.7	100	0	0
15	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
16	20	5	20	30	10	25	40	10	20	70	5	6.7	100	0	0
17	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
18	20	5	20	40	0	0	40	10	20	75	0	0	100	0	0
19	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
20	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
Mean % error	4			3.8			3			1.7			3.2		
Std. deviation	±13.6			±11.2			±11			±7			±5.6		

Back Ground
White

error = Actual Value - Approx. Value

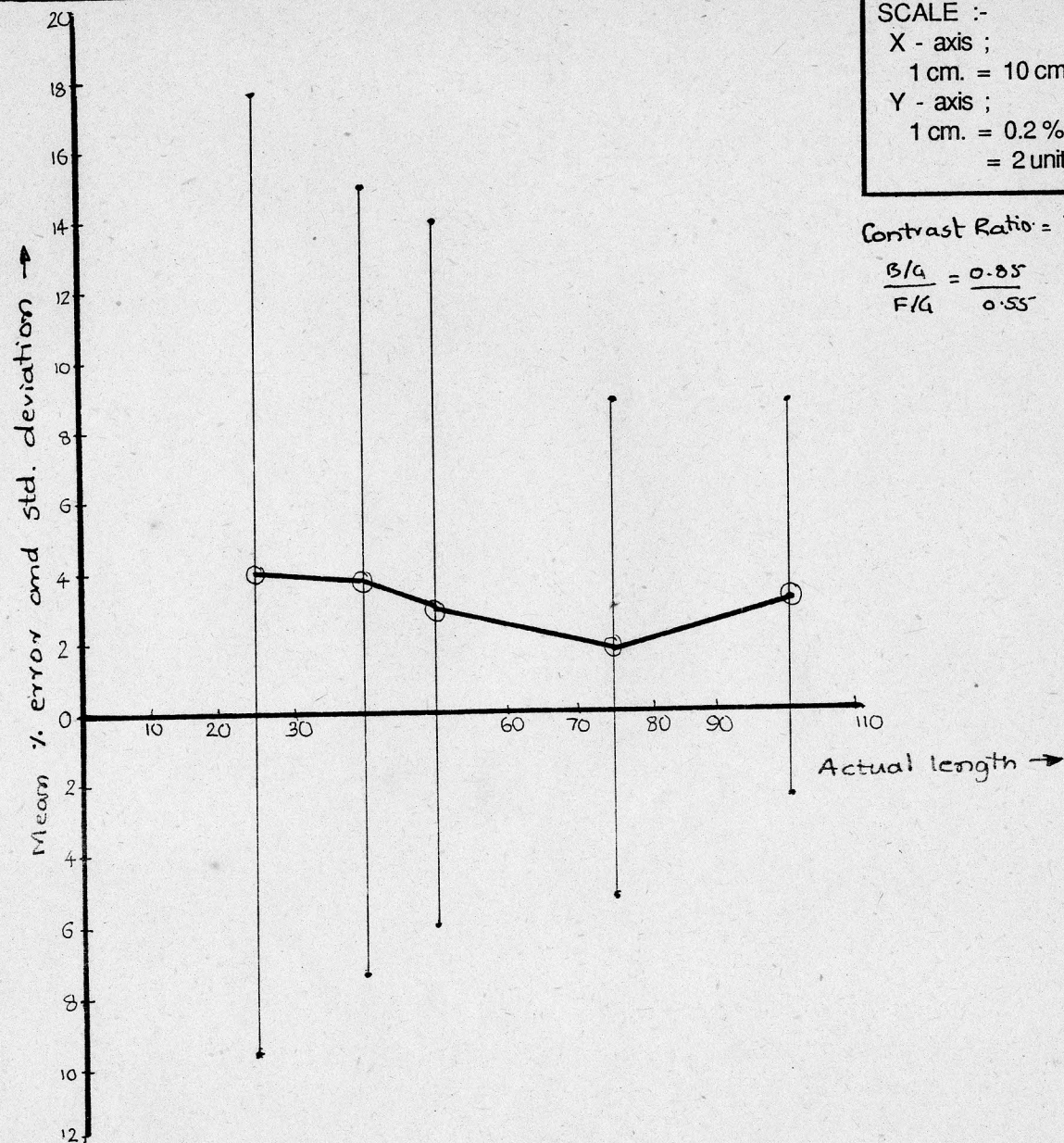
$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orietation	
Individual Vertical	

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio = 1.54:1

$$\frac{B/G}{F/G} = \frac{0.85}{0.55}$$



GRAPH OF ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 1.2

TABLE 2.1

Actual length →	1 cm.			2 cm.			4 cm.			5 cm.			10 cm.		
Subject ↓	aprxn	err.	%err.	aprxn	err.	%err.	aprxn	err.	%err.	aprxn	err.	%err.	aprxn	err.	%err.
1	1.8	-0.8	-80	2.5	-0.5	-25	4	0	0	5	0	0	10	0	0
2	0.9	0.1	10	1.6	0.4	20	3.5	0.5	12.5	4	1	20	7.5	2.5	25
3	1.5	-0.5	-50	2.7	-0.7	-35	4	0	0	5.2	-0.2	4	5.8	4.2	42
4	1.5	-0.5	-50	2.8	-0.8	-40	5	-1	-25	6	-1	-20	8	2	20
5	1.1	-0.1	-10	2.5	-0.5	-50	4.5	-0.5	-12.5	5	0	0	10	0	0
6	1.5	-0.5	-50	2	0	0	3	1	0	4	1	20	9	1	10
7	1.2	-0.2	-20	2	0	0	3	1	0	4	1	20	8	2	20
8	1.5	-0.5	-50	2.5	-0.5	-25	4.5	-0.5	-12.5	5	0	0	10	0	0
9	1	0	0	2.5	-0.5	-25	5	-1	-25	6	-1	-20	11	-1	-10
10	0.8	0.2	20	2	0	0	4.5	-0.5	-12.5	6	-1	-20	10	0	0
11	0.9	0.1	10	2	0	0	5	-1	-25	5.5	-0.5	-10	9	1	10
12	1.5	-0.5	-50	1.8	0.2	10	4	0	0	5	0	0	9	1	10
13	1.8	-0.8	-80	2	0	0	4	0	0	5	0	0	9	1	10
14	1.5	-0.5	-50	2.5	-0.5	-25	3	1	25	4	1	20	8	2	20
15	1.2	-0.2	-20	2	0	0	4.5	-0.5	-12.5	5	0	0	10	0	0
16	1.1	-0.1	-10	2	0	0	4.5	-0.5	-12.5	5	0	0	10	0	0
17	1.5	-0.5	-50	2.5	-0.5	-25	4	0	0	6	-1	-20	9	1	10
18	1	0	0	2	0	0	5	-1	-25	6	-1	-20	9	1	10
19	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
20	1.5	-0.5	-50	2	0	0	4	0	0	5	0	0	10	0	0
Mean % error		-30			-9.2			-1.2			-1.6			8.8	
Std. deviation		± 28.6			± 16.8			± 16.2			± 13.6			± 11.6	

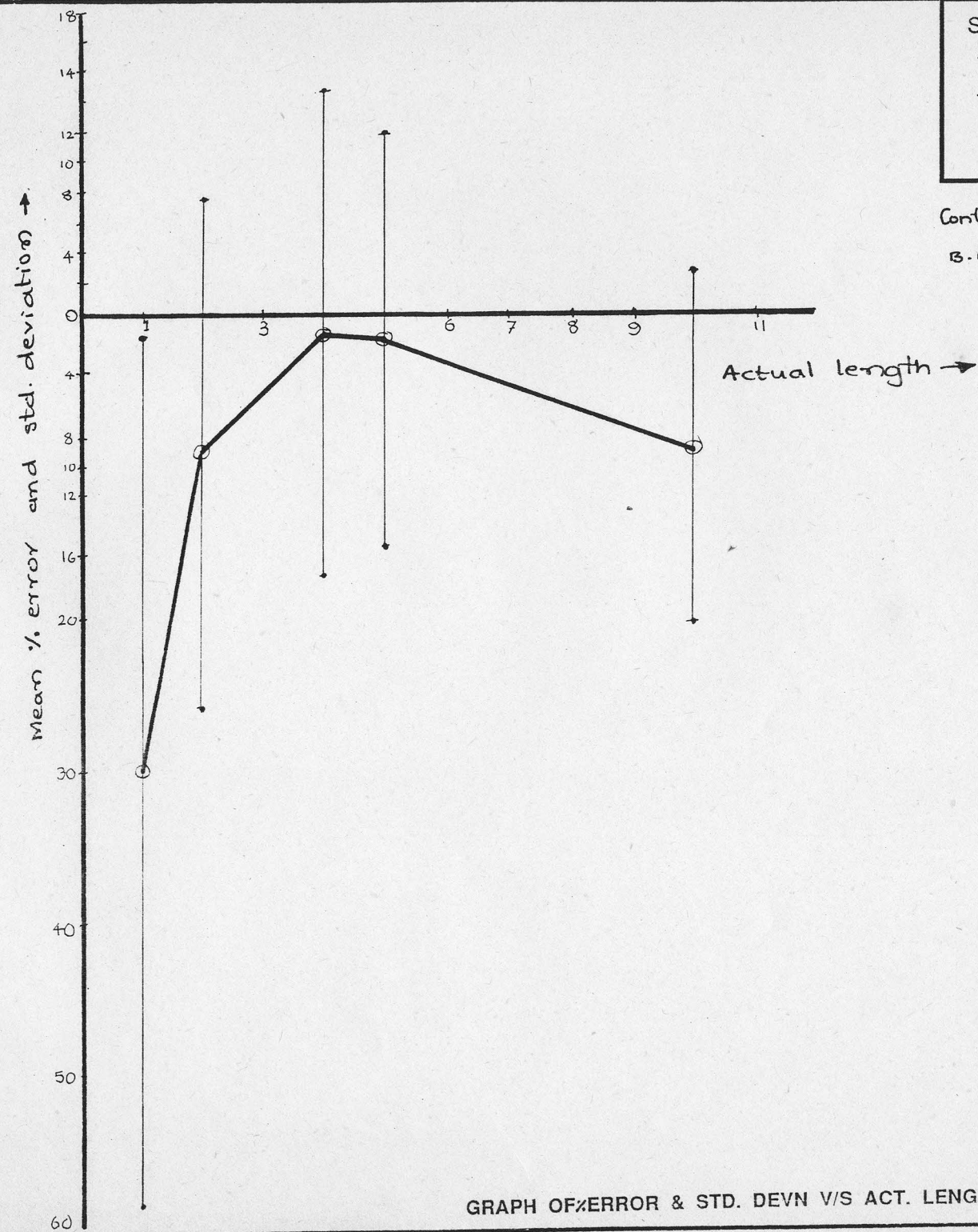
Back Ground
Blue

error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orientation

Individual Vertical	I
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SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.4 % err
 = 4 unit S.D.

Contrast Ratio = 0.9:1

B.G / F.G = 0.5 / 0.55

GRAPH OF %ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 2.1

TABLE 2.2

Actual length →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
Subject ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	30	-5	-20	45	-5	-12.5	55	-5	-10	90	-15	-20	100	0	0
2	18	7	28	33	7	17.5	38	12	24	60	15	26	95	5	5
3	25	0	0	35	5	12.5	40	2	4	60	15	20	90	10	10
4	20	5	20	30	10	25	40	10	20	60	15	20	90	10	10
5	18	7	28	35	5	12.5	40	10	20	70	5	6.7	100	0	0
6	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
7	25	0	0	40	0	0	50	0	0	70	5	6.7	90	10	10
8	30	-5	-20	45	-5	-12.5	55	-5	-10	80	-5	-6.7	100	0	0
9	28	-3	-12	30	10	25	40	10	20	70	5	6.7	90	10	10
10	20	5	20	45	-5	-12.5	55	-5	-10	80	-5	-6.7	100	0	0
11	25	0	0	35	5	12.5	45	5	10	70	5	6.7	90	10	10
12	30	-5	-20	50	-10	-25	60	-10	-20	80	-5	-6.7	100	0	0
13	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
14	22	3	12	35	5	12.5	45	5	10	70	5	6.7	90	10	10
15	20	5	20	30	10	25	40	10	20	70	5	6.7	80	20	20
16	20	5	20	35	5	12.5	45	5	10	70	5	6.7	100	0	0
17	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
18	23	2	8	40	0	0	50	0	0	70	5	6.7	90	10	10
19	25	0	0	35	5	12.5	45	5	10	70	5	6.7	100	0	0
20	20	5	20	40	0	0	50	0	0	70	5	6.7	100	0	0
Mean % error	5.2			5.2			5			3.3			4.8		
Std. deviation	±15.2			±13.6			±11.8			±10.3			±5.8		

Back Ground

Blue

error = Actual Value - Approx. Value

% error = $\frac{\text{error} \times 100}{\text{Act. Val.}}$

Act. Val.

Line Orientation

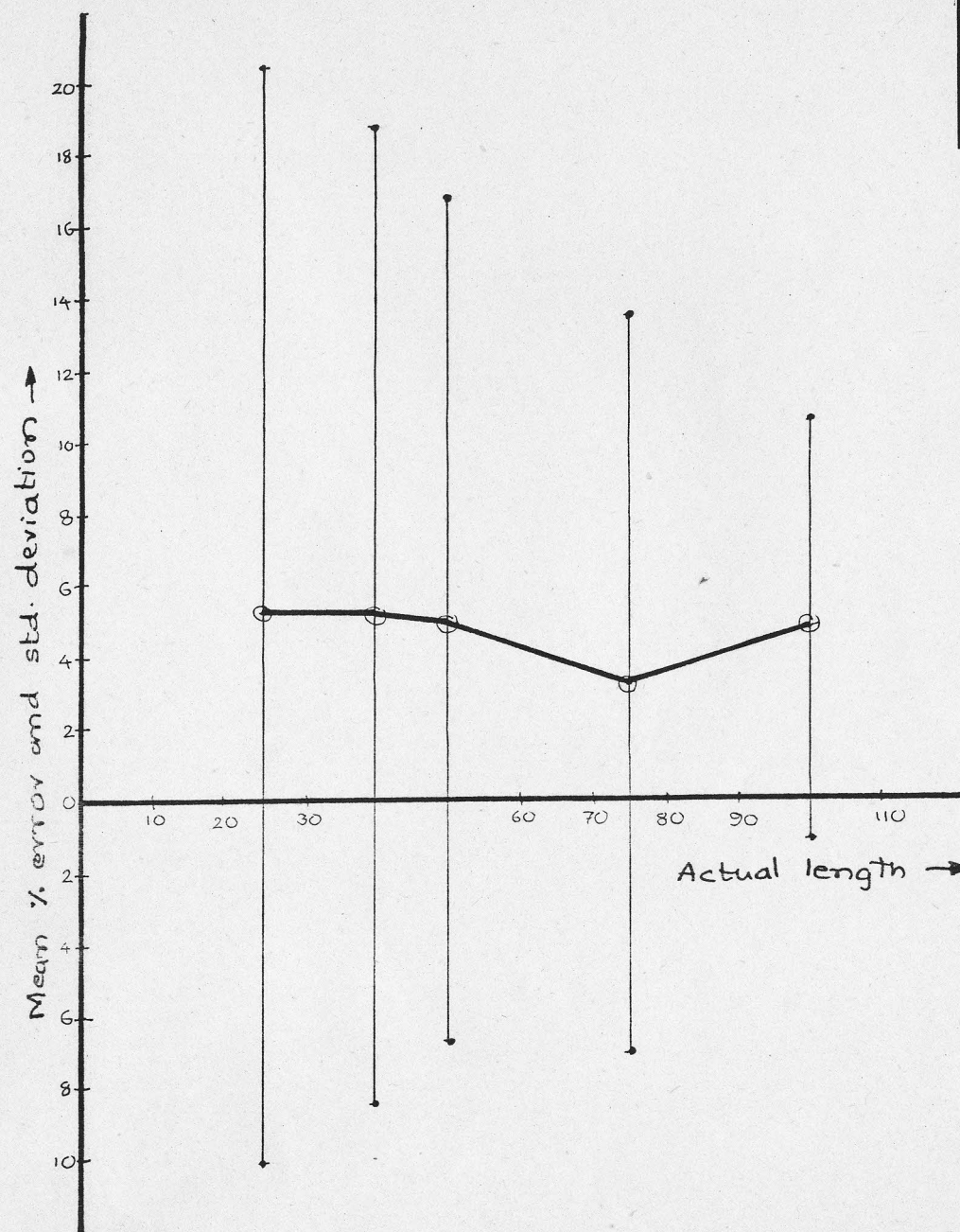
Individual
Vertical

|

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

contrast Ratio = 0.9 : 1

B.G/F.G = 0.5/0.55



GRAPH OF % ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 2.2

TABLE 3.1

<i>Actual length</i> →	1 cm.			2 cm.			5 cm.			4 cm.			10 cm.		
<i>Subject</i> ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	1.5	-0.5	-50	2.7	-0.7	-35	5	0	0	4	0	0	11	-1	-10
2	0.9	0.1	+10	1.6	0.4	20	4	1	20	3.5	0.5	12.5	10	0	0
3	1.7	-0.7	-70	2.7	-0.7	-35	5	0	0	5	-1	25	7.5	2.5	25
4	1.6	-0.6	-60	2.5	-0.5	-25	6	-1	-20	5	-1	25	11	-1	-10
5	1.2	-0.2	-20	2.2	-0.2	-10	6	-1	-20	3.5	0.5	12.5	11	-1	-10
6	1.1	-0.1	-10	2.1	-0.1	-5	5.5	-0.5	-10	4.5	-0.5	-12.5	11	-1	-10
7	1	0	0	2.5	-0.5	-25	5	0	0	4	0	0	10	0	0
8	0.9	0.1	10	2.5	-0.5	-25	4	1	20	3.5	0.5	12.5	8	2	20
9	0.8	0.2	20	2	0	0	5	0	0	4	0	0	10	0	0
10	0.9	0.1	10	2.5	-0.5	-25	4	1	20	3.5	0.5	12.5	9	1	10
11	1.1	-0.1	-10	2	0	0	5	0	0	4.5	-0.5	-12.5	11	-1	-10
12	1.5	-0.5	-50	2.2	-0.2	-10	6	-1	-20	5	-1	25	10	0	0
13	1.2	-0.2	-20	2.2	-0.2	-10	6	-1	-20	4	0	0	11	-1	-10
14	1.1	-0.1	-10	2	0	0	7	-2	-40	3.5	0.5	12.5	11	-1	-10
15	1	0	0	2	0	0	5.5	-0.5	-10	5	-1	-25	12	-2	-20
16	1	0	0	2.5	-0.5	-25	5	0	0	5	-1	-25	8	2	20
17	1.5	-0.5	-50	2.3	-0.3	-15	6	-1	-20	4	0	0	9	1	10
18	1.2	-0.2	-20	2.5	-0.5	-25	6	-1	-20	4.5	-0.5	-12.5	11	-1	-10
19	1	0	0	2.1	-0.1	-5	5	0	0	4	0	0	10	0	0
20	1	0	0	2	0	0	5	0	0	4	0	0	11	-1	-10
Mean % error	-16			-12.4			6.0			7.6			-1.2		
Std. deviation	±26			±14			±15.2			±12.8			±12		

Back Ground
Red

error = Actual Value - Approx. Value

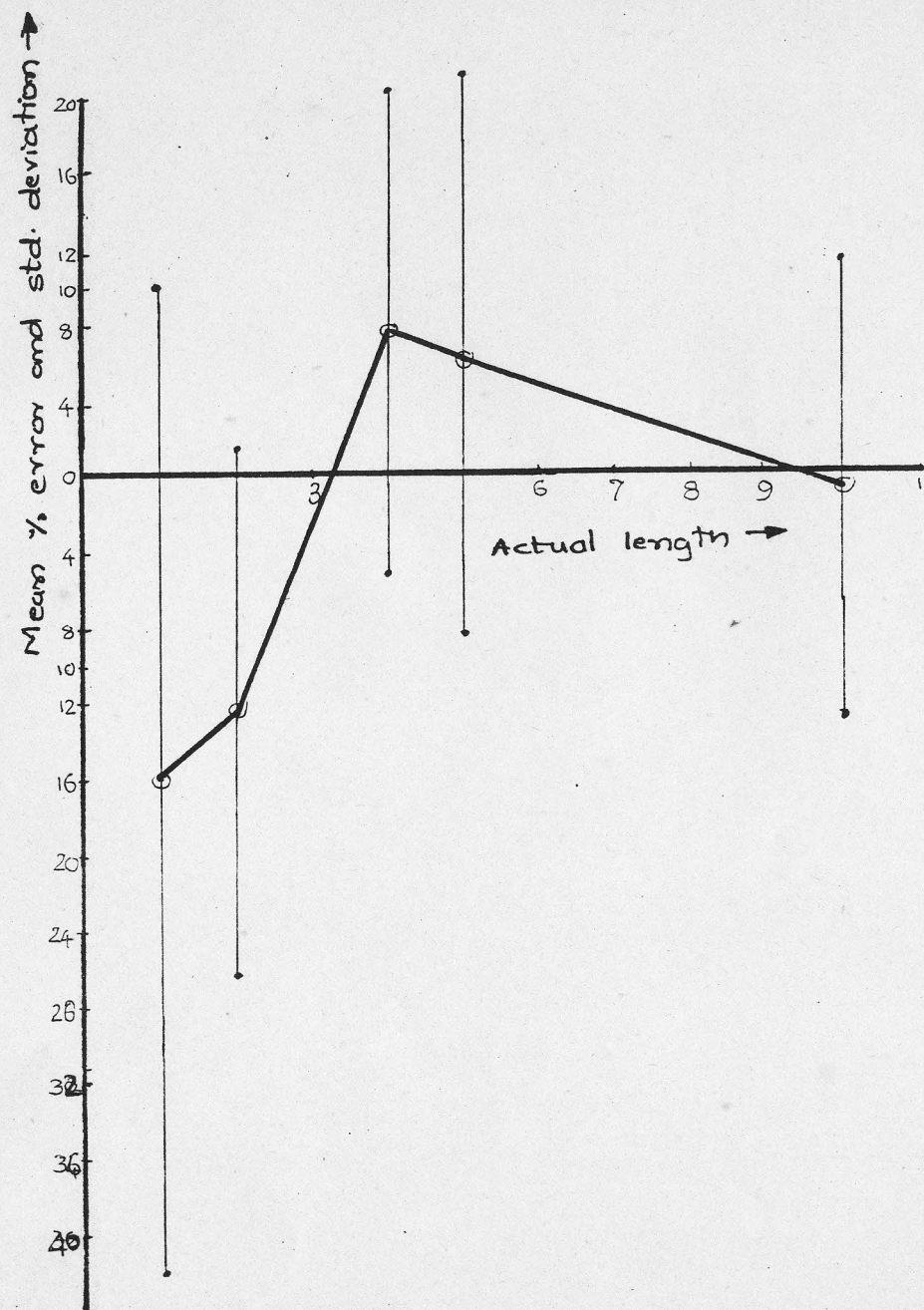
$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orietation	
Individual Vertical	I

SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.4 % err
 = 4 unit S.D.

Contrast Ratio = 0.8:1

B.G./F.G = 0.45/0.55



GRAPH OF %ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 3.1

TABLE 3.2

Actual length →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
Subject ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	30	-5	-20	50	-10	-25	60	-10	-20	90	-15	-20	100	0	0
2	20	5	20	35	+5	12.5	40	10	20	60	15	20	95	5	5
3	30	-5	-20	40	0	0	50	0	0	60	15	20	100	0	0
4	25	0	0	50	-10	-25	60	-10	-20	80	-5	-6.7	100	0	0
5	30	-5	-20	45	-5	-12.5	55	-5	-10	75	0	0	90	10	10
6	27	-2	-8	42	-2	-5	52	-2	-4	80	-5	-6.7	100	0	0
7	30	-5	-20	40	0	0	50	0	0	80	-5	-6.7	95	5	5
8	20	5	20	35	5	12.5	45	5	10	70	5	6.7	100	0	0
9	25	0	0	45	-5	-12.5	50	0	0	80	-5	-6.7	100	0	0
10	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
11	30	-5	-20	45	-5	-12.5	60	-10	-20	80	-5	-6.7	110	-10	-10
12	30	-5	-20	50	-10	-25	60	-10	-20	80	-5	-6.7	100	0	0
13	20	5	20	40	0	0	50	0	0	60	15	20	95	5	5
14	25	0	0	35	5	12.5	40	10	20	80	-5	-6.7	100	0	0
15	22	3	12	35	5	12.5	40	10	20	60	15	20	90	10	10
16	30	-5	-20	50	-10	-25	55	-5	-10	70	5	6.7	100	0	0
17	25	0	0	35	5	12.5	60	-10	-20	70	5	6.7	100	0	0
18	20	5	20	40	0	0	55	-5	-10	75	0	0	100	0	0
19	30	-5	-20	50	-10	-25	45	5	10	70	5	6.7	100	0	0
20	20	5	20	40	0	0	50	0	0	75	0	0	100	0	0
Mean % error	-1.8			-4.6			-1.7			2.4			1.8		
Std. deviation	±17			±14.6			±13.6			±11			±4.5		

Back Ground
Red

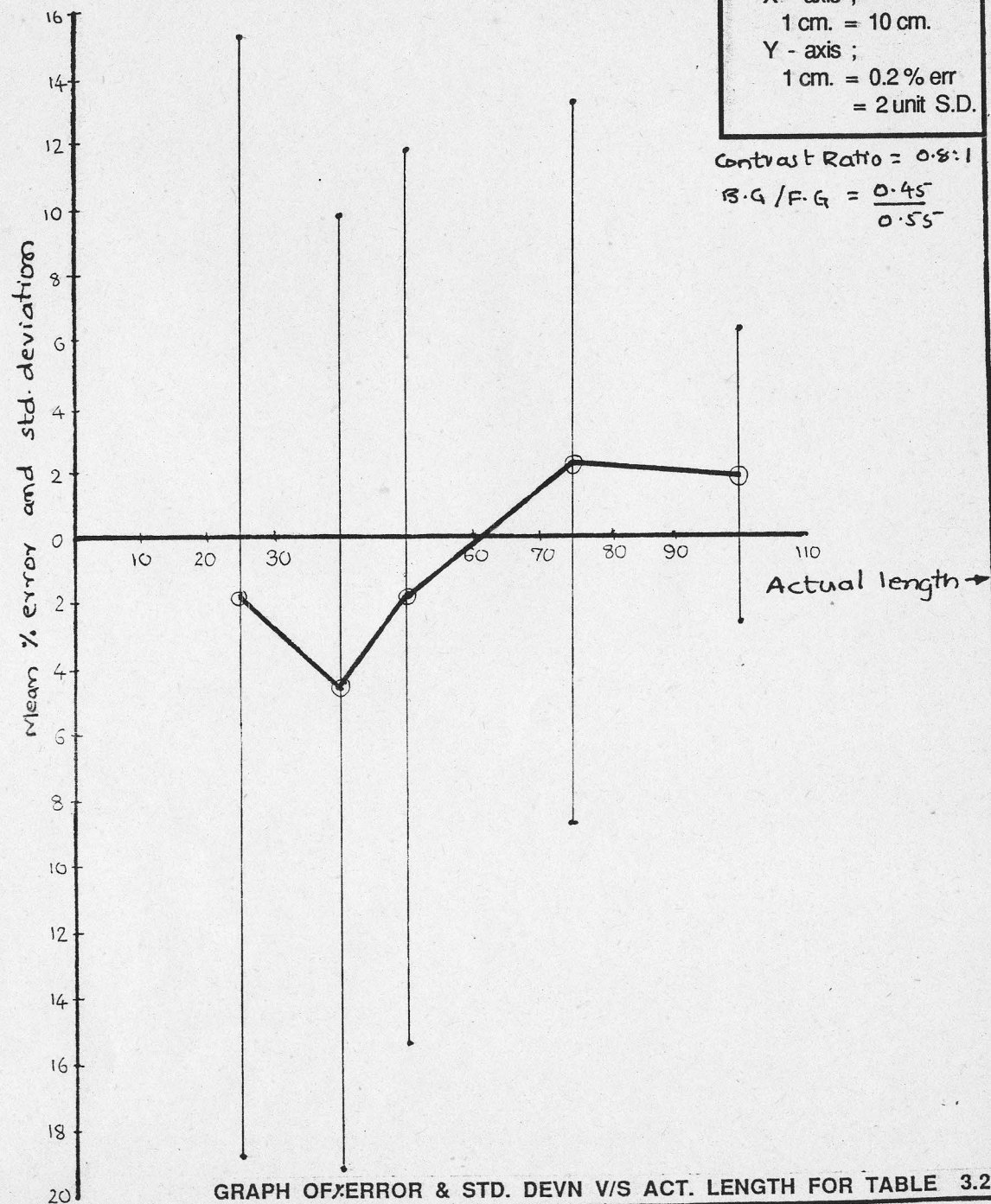
error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orietation	
Individual Vertical	

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio = 0.8:1
 $B.G / F.G = \frac{0.45}{0.55}$



GRAPH OF % ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 3.2

TABLE 4.1

Actual length →	1 cm.			2 cm.			4 cm.			5 cm.			10 cm.		
Subject ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	1.5	-0.5	-50	2.5	-0.5	-25	4	0	0	5	0	0	10	0	0
2	1	0	0	1.5	0.5	25	3.8	0.2	5	4.5	0.5	10	10	0	0
3	1.5	-0.5	-50	2.5	-0.5	-25	4.5	-0.5	-12.5	5	0	0	8	2	20
4	1.5	-0.5	-50	2.0	0	0	4.5	-0.5	-12.5	5.5	-0.5	-10	10	0	0
5	1	0	0	2.0	0	0	3.8	0.2	5	5.5	-0.5	-10	10	0	0
6	1	0	0	2.0	0	0	4	0	0	5	0	0	10	0	0
7	1	0	0	2.5	-0.5	-25	4	0	0	5	0	0	10	0	0
8	1	0	0	2	0	0	3.8	0.2	5	4.5	0.5	10	9	1	10
9	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
10	1.1	-0.1	-10	2	0	0	3.8	0.2	5	4.5	0.5	10	10	0	0
11	1.1	-0.1	-10	2	0	0	4	0	0	5	0	0	10	0	0
12	1.1	-0.1	-10	2.2	-0.2	-10	4.5	-0.5	-12.5	5.5	-0.5	-10	11	-1	-10
13	1.1	-0.1	-10	2	0	0	4	0	0	5	0	0	10	0	0
14	1	0	0	2	0	0	4	0	0	6	-1	-20	11	-1	-10
15	1	0	0	2	0	0	4.5	-0.5	-12.5	5	0	0	9	1	10
16	1	0	0	2.5	-0.5	-25	4.5	-0.5	-12.5	5	0	0	10	0	0
17	1.2	-0.2	-20	2	0	0	4	0	0	5	0	0	10	0	0
18	1	0	0	2.5	-0.5	-25	4	0	0	5.5	-0.5	-20	10	0	0
19	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
20	1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
Mean % error	-10			-5.5			-2.3			-1.6			1		
Std. deviation	±17			±12.8			±6.2			±8			±6		

Back Ground
Yellow

error = Actual Value - Approx. Value

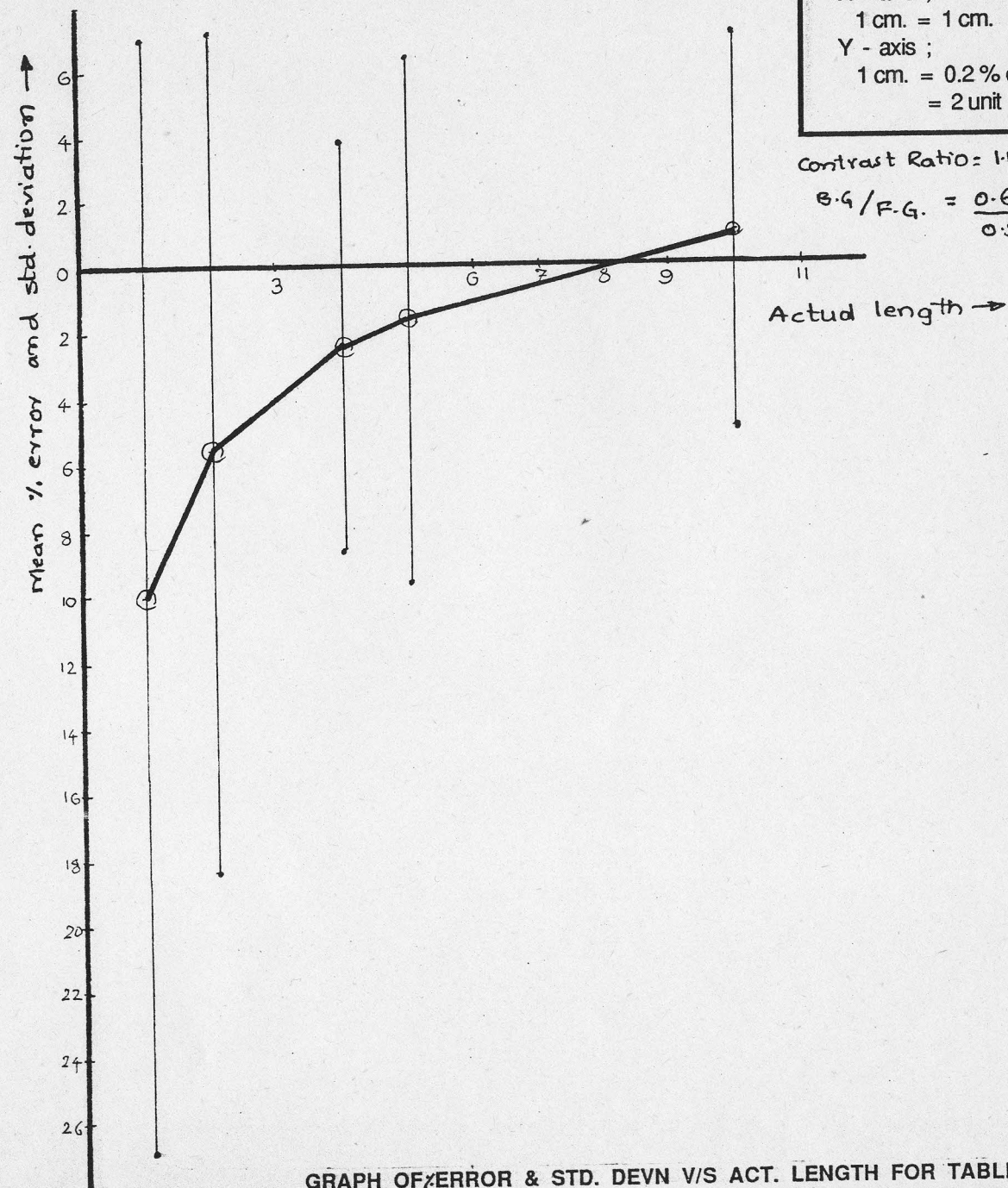
$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orientation	
Individual Vertical	I

SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio: 1:1 : 1

$$B.G / F.G. = \frac{0.6}{0.55}$$



GRAPH OF % ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 4.1

TABLE 4.2

<i>Actual length</i> →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
<i>Subject</i> ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	30	-5	-20	40	0	0	50	0	0	80	-5	-6.7	100	0	0
2	25	0	0	35	5	12.5	45	5	10	60	15	20	90	10	10
3	30	-5	-20	40	0	0	50	0	0	60	15	20	100	0	0
4	25	0	0	45	-5	-12.5	55	-5	-10	80	-5	-6.7	100	0	0
5	25	0	0	40	0	0	50	0	0	75	0	0	90	10	10
6	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
7	25	0	0	40	0	0	50	0	0	70	5	6.7	90	10	10
8	20	5	20	35	5	12.5	45	5	10	70	5	6.7	100	0	0
9	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
10	20	5	20	40	0	0	45	5	10	70	5	6.7	100	0	0
11	25	0	0	45	-5	-12.5	50	0	0	75	0	0	110	-10	-10
12	30	-5	-20	40	0	0	55	-5	-10	70	5	6.7	110	-10	-10
13	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
14	25	0	0	35	5	12.5	45	5	10	70	5	6.7	100	0	0
15	20	5	20	40	0	0	50	0	0	70	5	6.7	110	-10	-10
16	30	-5	-20	40	0	0	50	0	0	70	5	6.7	100	0	0
17	25	0	0	40	0	0	55	-5	-10	70	5	6.7	100	0	0
18	20	5	20	40	0	0	50	0	0	75	0	0	100	0	0
19	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
20	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
Mean % error	0			0.6			0.5			4.2			0		
Std. deviation	±12.8			±6			±6			±7			±5.5		

Back Ground
Yellow

error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orietation	
Individual Vertical	

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio = 14:1

$$\frac{B.G}{F.4} = \frac{0.6}{0.55}$$

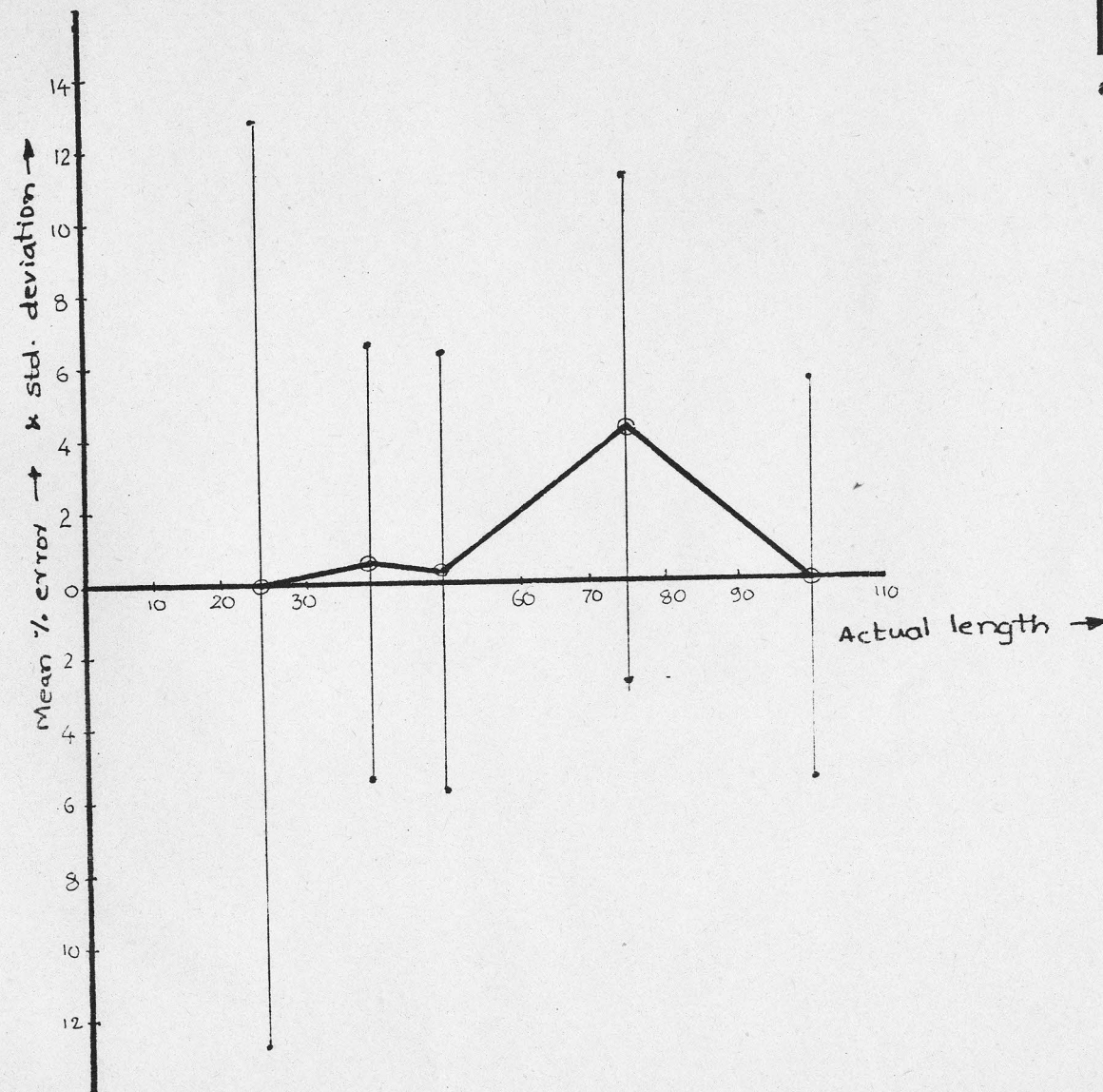


TABLE 5.1

Actual length →		1 cm.			2 cm.			4 cm.			5 cm.			10 cm.		
Subject ↓		aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1		1.5	-0.5	-50	2	0	0	4	0	0	6	-1	-20	10	0	0
2		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
3		1.5	-0.5	-50	2.1	-0.1	-5	4.5	-0.5	-12.5	5.5	-0.5	-10	11	-1	-10
4		1.4	-0.4	-40	2.2	-0.2	-10	5	-1	-25	6	-1	-20	11	-1	-10
5		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
6		1	0	0	2	0	0	5	-1	-25	6	-1	-20	11	-1	-10
7		1.5	-0.5	-50	2.5	-0.5	-25	5	-1	-25	6	-1	-20	12	-2	-20
8		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
9		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
10		1.5	-0.5	-50	2.5	-0.5	-25	5	-1	-25	6	-1	-20	12	-2	-20
11		1.2	-0.2	-20	2	0	0	4	0	0	4.5	0.5	10	9	1	10
12		1	0	0	2	0	0	3	1	25	4	1	20	8	2	20
13		1.5	-0.5	-50	2.5	-0.5	-25	5	-1	-25	6	-1	-20	12	-2	-20
14		0.8	0.2	20	1.8	0.2	10	3.5	0.5	12.5	4.5	0.5	10	9	1	10
15		0.9	0.1	10	2	0	0	3.5	0.5	12.5	4.5	0.5	10	9	1	10
16		1.1	-0.1	-10	2.1	-0.1	-5	4.5	-0.5	-12.5	6	-1	-20	12	-2	-20
17		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
18		1	0	0	2	0	0	4	0	0	5	0	0	10	0	0
19		1.5	-0.5	-50	2.5	-0.5	-25	5	-1	-25	6	-1	-20	12	-2	-20
20		1.5	-0.5	-50	2.5	-0.5	-25	5	-1	-25	6	-1	-20	12	-2	-20
Mean % error		-20			-6.9			-7.6			-7			-5		
Std. deviation		±25			±11			±15			±13			±12		

Back Ground

White

error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

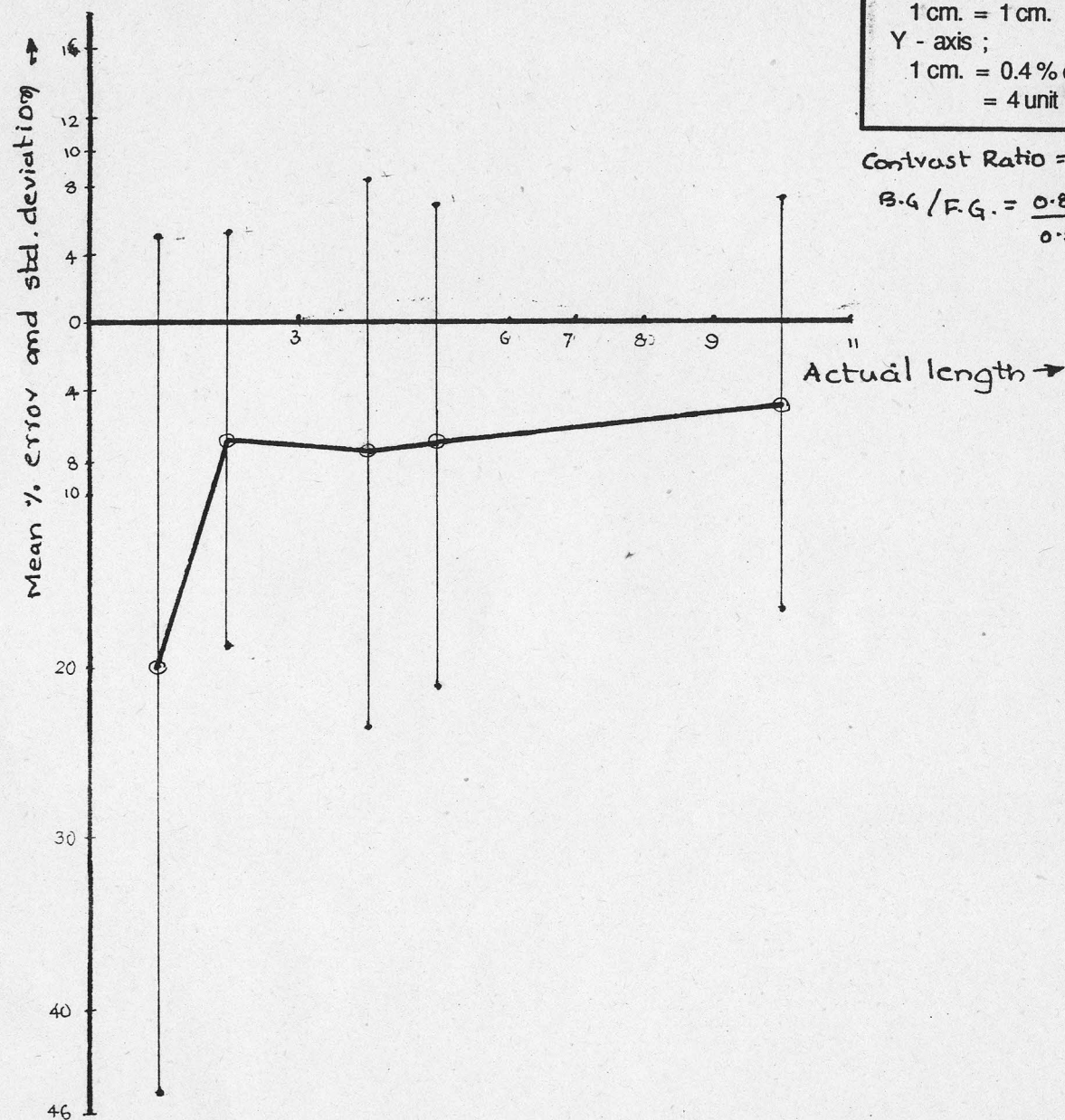
Line Orientation

Group
Vertical

SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.4 % err
 = 4 unit S.D.

Contrast Ratio = 1.54

$$B.G. / F.G. = \frac{0.85}{0.55}$$



GRAPH OF ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 5.1

TABLE 5.2

Actual length →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
Subject ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
2	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
3	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
4	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
5	20	5	20	35	5	12.5	45	5	10	75	0	0	100	0	0
6	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
7	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
8	20	5	20	40	0	0	50	0	0	80	-5	-6.7	100	0	0
9	20	5	20	40	0	0	50	0	0	80	-5	-6.7	100	0	0
10	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
11	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
12	20	5	20	40	0	0	50	0	0	70	5	6.7	100	0	0
13	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
14	20	5	20	35	5	12.5	45	5	10	70	5	6.7	100	0	0
15	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
16	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
17	20	5	20	40	0	0	50	0	0	75	0	0	100	0	0
18	20	5	20	40	0	0	50	0	0	70	5	6.7	90	10	10
19	25	0	0	35	5	12.5	45	5	10	70	5	6.7	100	0	0
20	25	0	0	40	0	0	45	5	10	75	0	0	100	0	0
Mean % error	11			4.4			4			1.8			2.5		
Std. deviation	±10			±6			±5			±5			±4.2		

Back Ground
White

error = Actual Value - Approx. Value

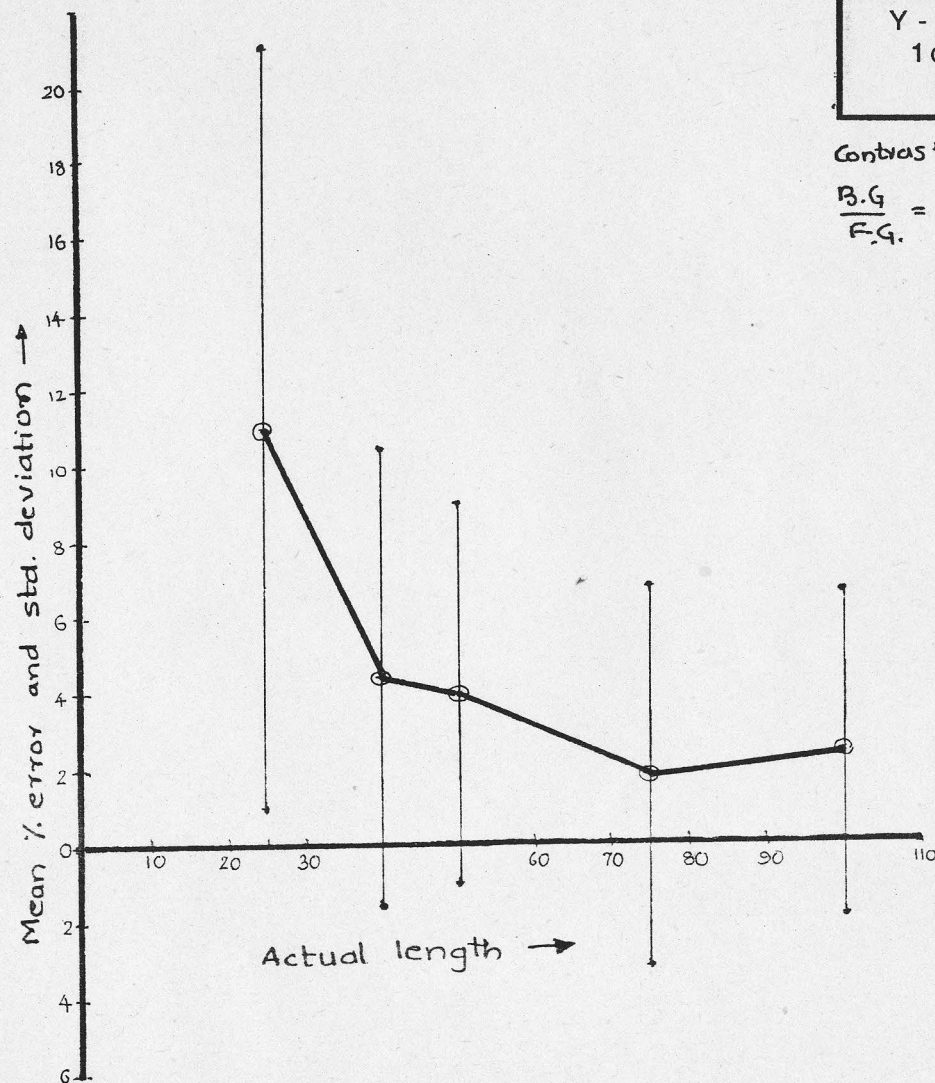
$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

Line Orientation	
Group Vertical	

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio = 1.54 : 1

$$\frac{B.G.}{F.G.} = \frac{0.85}{0.55}$$



GRAPH OF % ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 5.2

TABLE 6.1

<i>Actual length</i> →	1 cm.			2 cm.			4 cm.			5 cm.			10 cm.		
<i>Subject</i> ↓	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err	aprxn	err	%err
1	1.5	-0.5	-50	2.5	-0.5	-25	4.5	-0.5	-12.5	5.5	-0.5	-10	9	1	10
2	1.4	-0.4	-40	2.2	-0.2	-10	4.5	-0.5	-12.5	6	-1	-20	8	2	20
3	1.3	-0.3	-30	1.5	0.5	+25	4.5	-0.5	-12.5	5.5	-0.5	-10	9	1	10
4	1	0	0	1.8	0.2	+10	4	0	0	5	0	0	10	0	0
5	1.2	-0.2	-20	1.8	0.2	+10	3.5	0.5	12.5	4.5	0.5	10	11	-1	-10
6	1.2	-0.2	-20	1.5	0.5	+25	3.5	0.5	12.5	4.5	0.5	10	12	-2	-20
7	1.1	-0.1	-10	2.5	-0.5	-25	4.5	-0.5	-12.5	5	0	0	11	-1	-10
8	1.3	-0.3	-30	2.2	-0.2	-10	4.5	-0.5	-12.5	5	0	0	11	-1	-10
9	1.4	-0.4	-40	2.1	-0.1	-5	4	0	0	5	0	0	11	-1	-10
10	1.2	-0.2	-20	2.5	-0.5	-25	4	0	0	5	0	0	11	-1	-10
11	1.1	-0.1	-10	1.9	0.1	5	3.5	0.5	12.5	4.5	0.5	10	9	1	10
12	1	0	0	1.7	0.3	15	3.5	0.5	12.5	4.5	0.5	10	11	-1	-10
13	0.8	0.2	20	1.5	0.5	25	3.5	0.5	12.5	4.5	0.5	10	9	1	10
14	1.1	-0.1	-10	2.5	-0.5	-25	4.5	-0.5	-12.5	5.5	-0.5	-10	9	1	10
15	0.9	0.1	10	2.2	-0.2	-10	4.5	-0.5	-12.5	5.5	-0.5	-10	11	-1	-10
16	0.8	0.2	20	2	0	0	4	0	0	5.5	-0.5	-10	12	-2	-20
17	0.7	0.3	30	2.5	-0.5	-25	4	0	0	5.5	-0.5	-10	12	-2	-20
18	1.5	-0.5	-50	2	0	0	4	0	0	5	0	0	11	-1	-10
19	1.4	-0.4	-40	2	0	0	4	0	0	5	0	0	11	-1	-10
20	1.5	-0.5	-50	2	0	0	4	0	0	5	0	0	11	-1	-10
Mean % error	-17			-2.2			-1.2			0.5			-4.5		
Std. deviation	±24			±16.8			±9.6			±8.6			±11.6		

Back Ground

White

error = Actual Value - Approx. Value

% error = $\frac{\text{error} \times 100}{\text{Act. Val}}$

Line Orietation

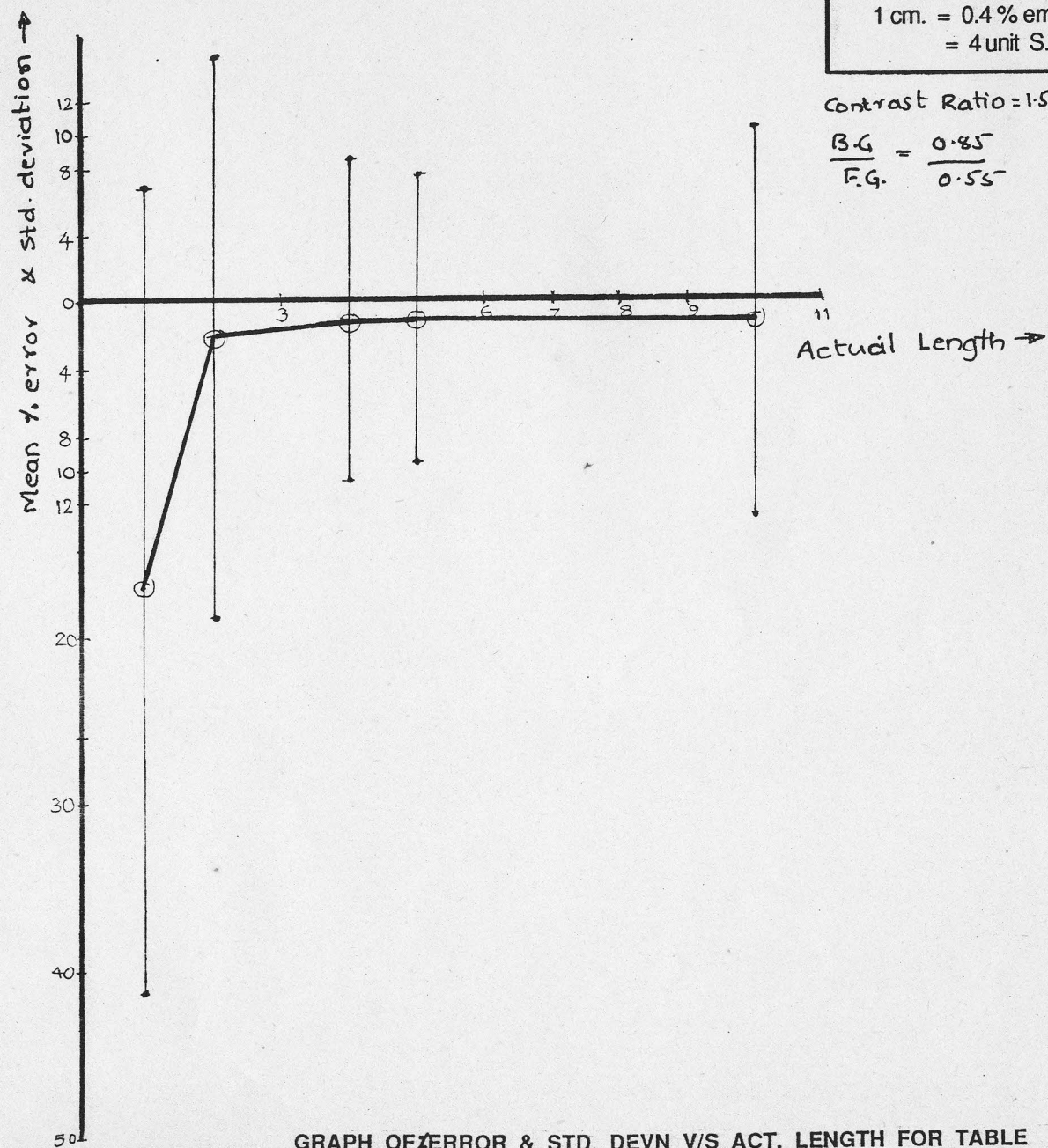
Random
Vertical



SCALE :-
 X - axis ;
 1 cm. = 1 cm.
 Y - axis ;
 1 cm. = 0.4 % err
 = 4 unit S.D.

Contrast Ratio = 1.54:1

$$\frac{B.G.}{F.G.} = \frac{0.85}{0.55}$$



GRAPH OF ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 6.1

TABLE 6.2

Actual length →	25 cm.			40 cm.			50 cm.			75 cm.			100 cm.		
Subject ↓	aprxn	err.	%err	aprxn	err.	%err	aprxn	err.	%err	aprxn	err.	%err	aprxn	err.	%err
1	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
2	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
3	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
4	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
5	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
6	25	0	0	40	0	0	50	0	0	70	5	6.7	100	0	0
7	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
8	20	5	20	35	5	12.5	45	5	10	70	5	6.7	90	10	10
9	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
10	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
11	22	3	12	35	5	12.5	45	5	10	70	5	6.7	90	10	10
12	22	3	12	35	5	12.5	45	5	10	70	5	6.7	90	10	10
13	25	0	0	40	0	0	50	0	0	80	-5	-6.7	100	0	0
14	20	5	20	40	0	0	50	0	0	80	-5	-6.7	100	0	0
15	25	0	0	40	0	0	60	-10	-20	80	-5	-6.7	100	0	0
16	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
17	25	0	0	40	0	0	50	0	0	75	0	0	100	0	0
18	22	3	12	35	5	12.5	50	0	0	70	5	6.7	90	10	10
19	22	3	12	35	5	12.5	50	0	0	70	5	6.7	90	10	10
20	22	3	12	35	5	12.5	50	0	0	70	5	6.7	100	0	0
Mean % error	9			6.2			2.5			1.5			4.5		
Std. deviation	± 8.6			± 6.2			± 7			± 4.2			± 5		

Back Ground

White

error = Actual Value - Approx. Value

$$\% \text{ error} = \frac{\text{error} \times 100}{\text{Act. Val}}$$

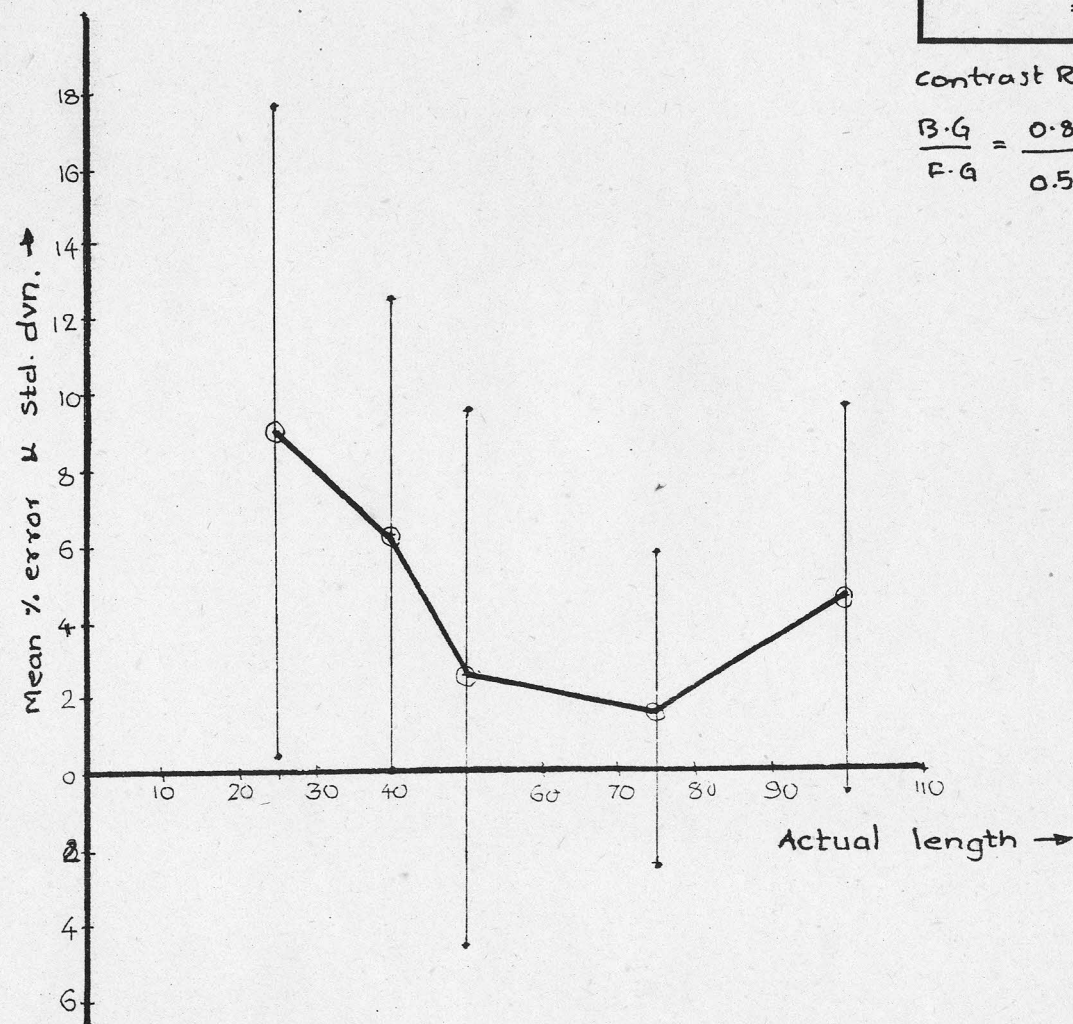
Line Orientation

Random
Vertical

SCALE :-
 X - axis ;
 1 cm. = 10 cm.
 Y - axis ;
 1 cm. = 0.2 % err
 = 2 unit S.D.

Contrast Ratio = 1.54:1

$$\frac{B.G}{F.G} = \frac{0.85}{0.55}$$



GRAPH OF ERROR & STD. DEVN V/S ACT. LENGTH FOR TABLE 6.2

6. ANALYSIS

From the graphs we can observe that approximated value, in the case of shorter length lines (i.e. 1cm to 10cm) is more than actual value in all cases, and in case of longer lines (i.e. 25cm to 100cm) approximated value is less than the actual value. These deviation patterns are indicated in the graphs where mean % error points are on negative side in case of lines of shorter lengths and values of mean % error are on positive side in case of lines of longer lengths. The deviation factor implies possibility of committing error in judging the value in erratic way is less.

There is also a graph which shows an erratic behaviour of the deviation pattern. This is in the case of judging the length of the lines when background colour is 'Red'. This is because of lower contrast ratio. So possibility of committing error in erratic way is more when contrast ratio is less.

When there is a group of lines, the deviation pattern is smooth. This implies error in judging a value is gradual. This might be due to subject judging a value using relative judgement.

We can conclude from this study that people approximate the values more in case of shorter length lines & approximate less in case of longer length lines. Deviation pattern will be smooth if contrast ratio is more.

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