SLIDE RULE FOR SCHOOLCHILDREN

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1975

SLIDE RULE FOR SCHOOLCHILDREN

Diploma Project

Submitted in partial fulfilment of
the requirements of the Postgraduate Diploma
in Industrial Design

by

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Industrial Design Centre
Indian Institute of Technology
Bombay

1975

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Approval Sheet

Diploma Project entitled

SLIDE RULE FOR SCHOOLCHILDREN

by S.R. Gursahani is approved for the Postgraduate Diploma in Industrial Design

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A C K N O W L E D G E M E N T S

I wish to express my deep sense of gratitude to Shri Gopinath Rao and Shri M.C.Chattopadhyaya for their guidance, help and encouragement. I would also like to thank Prof.S.Nadkarni for his help and constant encouragement.

It would have been impossible to complete this project without the help of numerous friends, specially Shri Anupam Gupta, and the staff of the Industrial Design Centre.

I am indebted to Shri Khan and Shri L.Jethwa of M/S Bright Brothers for their help and advice.

Deeva Pvt.Ltd. were helpful in supplying the information on their slide rules.

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1.0 INTRODUCTION

The Slide Rule is an extremely useful instrument for making various kinds of calculations, especially multiplication and division. Its use, in India, is however restricted to technical colleges and in some cases to science students. The speed and accuracy with which these calculations can be done should lead to a much wider use.

There are two factors which have probably prevented the use of the slide rule on a large scale.

(i) The complexity of the slide rule scales. The errors which a learner makes might easily discourage him from using it.

(ii) The prohibitive cost of the instrument reduces its potential for a widespread use.

The need then, is to design a slide rule which will be simple to use, which will have a few, but easily understandable scales and which will not cost much.

Such a slide rule, it is hoped, will be adopted in schools. With new and slightly complex courses being introduced at school level (especially in Higher Secondary Schools) there is an

increasing need to make quick calculations. As it is, in the higher classes, students use log tables which is quite a laborious process.

The slide rule scales are based on the same principle of logarithms and should present no particular difficulty in understanding.

The accuracy desired to be attained here is to three significant figures. This is of course, less than what one can achieve with logarithm tables. But, more often than not, an accuracy of more than three significant figures is not required specially when the calculations have to be made rather fast.

Such a slide rule need not be restricted to schools only. It can be used by anybody who needs a simple device to do his multiplications and divisions.

2.0 INFORMATION

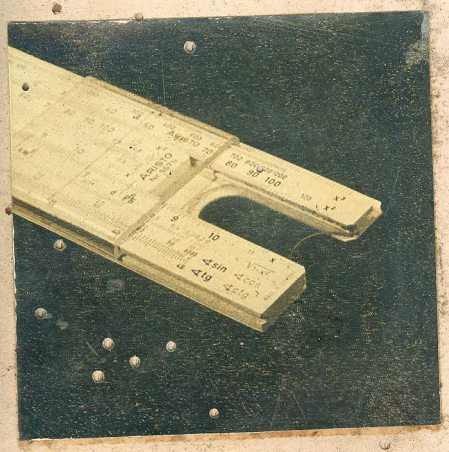
2.1 TYPES OF SLIDE RULES

Slide rules are made in various shapes. The most commonly used is the straight slide rule. Among the other shapes the circular is used more often than the other shapes.

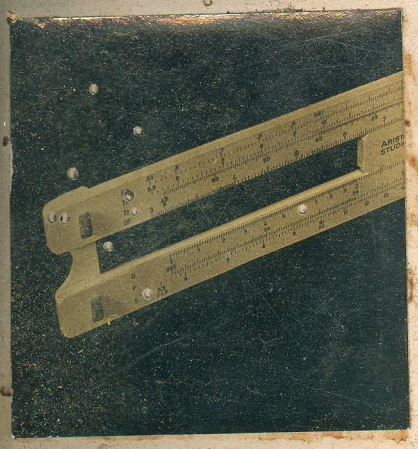
2.2 THE STRAIGHT SLIDE RULE

The straight slide rule consists of three principal parts - the stock (or frame), the slide, and the cursor (or runner).

There are two forms of straight slide rules which are in common use. These are the Mannheim type and the Duplex type.



The Mannheim type has a solid back to the frame, and therefore has scales on one side only. But some have scales on both faces of the slide. The scales on the back of the slide are used by removing the slide and turning it over, or by reading opposite a scribed glass or gauge mark at the end of the frame.



The Duplex slide rule has two outer strips held together by a pair of end caps. Some slide rules have adjustable end caps, but most have them permanently secured. The slide moves freely, but not loosely, between the strips. This type of slide rule has scales on both faces of stock and slide.

2.21 STOCK AND SLIDE

The most common materials used for the construction of the stock and slide are thermoplastics. Polyacetal, ABS and PVC are commonly used.

In most precision slide rules the stock and slide are manufactured by machining. In some cases, however, the injection moulding process is used.

2.22 END CAPS

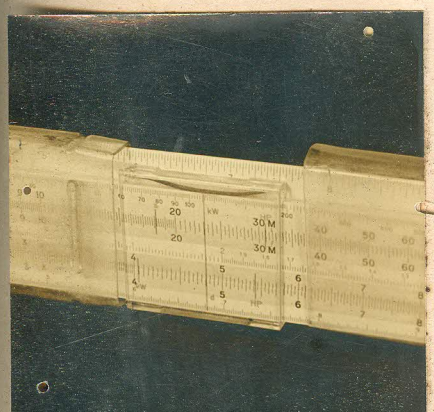
The end caps are generally moulded. The material used is the same as that used for the stock, or a different material like H.I. Polystyrene is used. The end caps are then fitted on to the outer strips to form the stock. The tendency is to weld the end caps

permanently rather than to provide screws for alignment.

There are, of course, no end caps for the Mannheim type of slide rule.

2.23 THE CURSOR

The cursor is a 'glass' which is fastended to edge pieces, or the glass itself may be bent at the edges. One of edges carries a flat spring to control the movement of the cursor.



On the centre of the glass there is a hairline perpendicular to the scale lines. There are very often other hairlines at some distance from the centre one which are indications for some constants. [Area of circle, kW-HP conversion, etc.

There is one 'glass' on the Mannheim type, whereas there are two on the Duplex. In the Duplex the hailines on the two faces have to be in perfect alignment.

The cursor 'glasses' are generally made from acrylic. The edge pieces can be molded H.I. Polystyrene (or some other thermoplastic), or the entire cursor may be of acrylic moulded in two identical parts (in case of the Duplex).

The Mannheim slide rule having only one face has a single piece acrylic cursor.

2.3 THE CIRCULAR SLIDE RULE

Also known as Disc Calculator. This type usually has two discs of different diameters which can be rotated with respect to each other.

The principle is the same as the ordinary slide rule - logarthmic scales plotted on a circular scale line. They generally have a very few scales besides C and D.

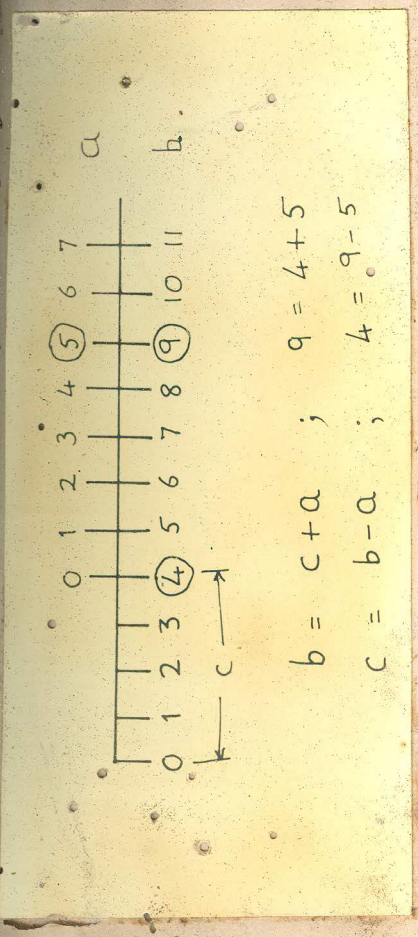
2.4 PRINCIPLE OF THE SLIDE RULE.

The slide rule performs multiplication, division and other mathematical operations by one or a sequence of the following basic mechanical operations

a) Subtract Lengths

b) Add Lengths

c) Equate Lengths



The mathematical principle used in multiplication and division is based on the properties of logarithms.

Division : If the logarithm of one number is subtracted from the logarithm of another, the difference is the logarithm of the quotient.

Multiplication : If the logarithm of the first factor is added to the logarithm of a second factor, the sum is equal to the logarithm of the product.

2.5 SLIDE RULE SCALES

A large number of scales have been designed for use on slide rules. Most of these scales are non-linear (not uniformly graduated) and are used for a number of mathematical operations including multiplication and division.

2.51 TYPE OF SCALES

The Basic Scale on a slide rule is that one from which the other scales of the same type are derived.

The Basic Decade on a logarithmic slide rule has values x ranging from 1 to 10, increasing from left to right, the graduation distances being proportional to log x .

Fixed Conjugate Scales are those in a fixed position relative to each other. They represent different functions of x of the basic decade.

Sliding Conjugate Scales are those capable of being moved relative to each other.

An Extended Scale is one in which the graduations are taken beyond the ends of the basic decade length.

A Folded Scale, relative to the basic decade, is one which has been severed at a particular graduation, and one part 'folded' over or transferred to the other end.

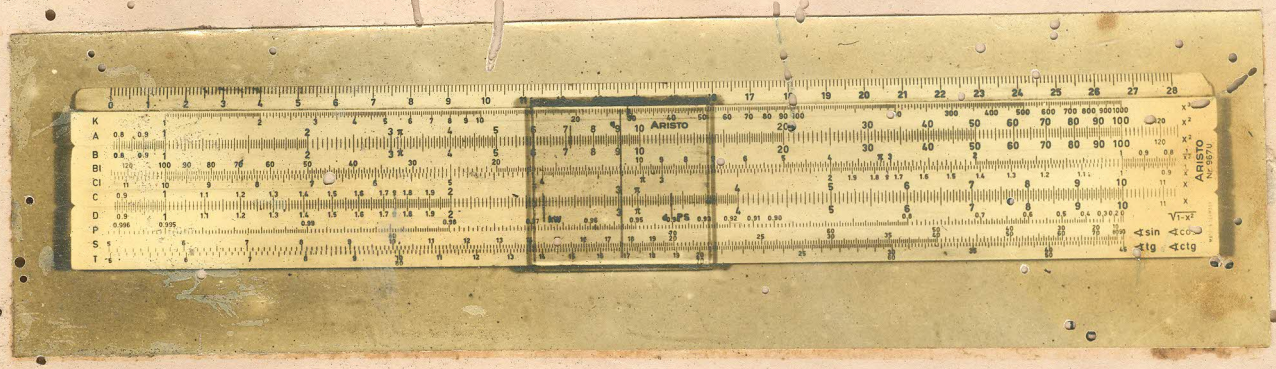
An Inverse Scale has its numbers increasing to the left instead of to the right.

2.52 SCALE LAYOUT

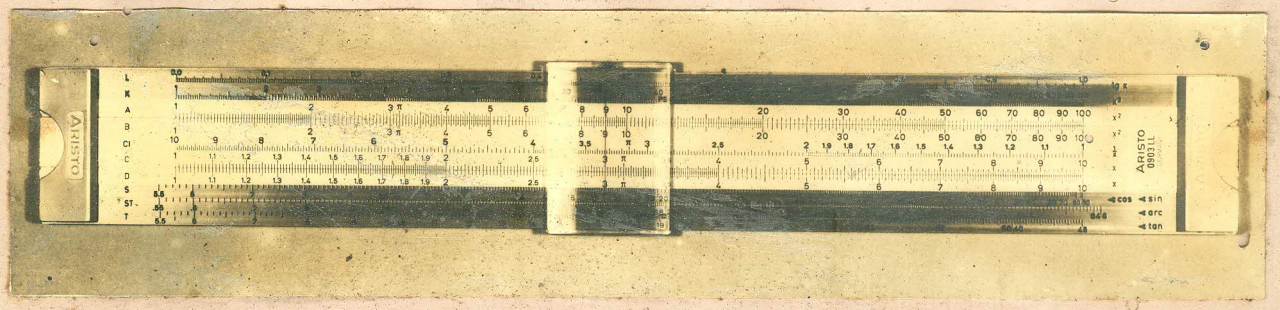
To the left of each scale are capital letters which are the generally recognized designations for the scales. Some scales retain their designations whether on the stock or slide ; others, such as D, DI, DF etc., become C, CI, CF, etc., when on the slide. To the right of each scale is the function indicating how the values are related to the basic decade.

Scales can be open ended or have boundary lines. They are useful if the scales are hand - marked but otherwise their use has no particular function. In fact, some studies seem to indicate that an open - ended scale is easier to interpolate between the graduation marks.

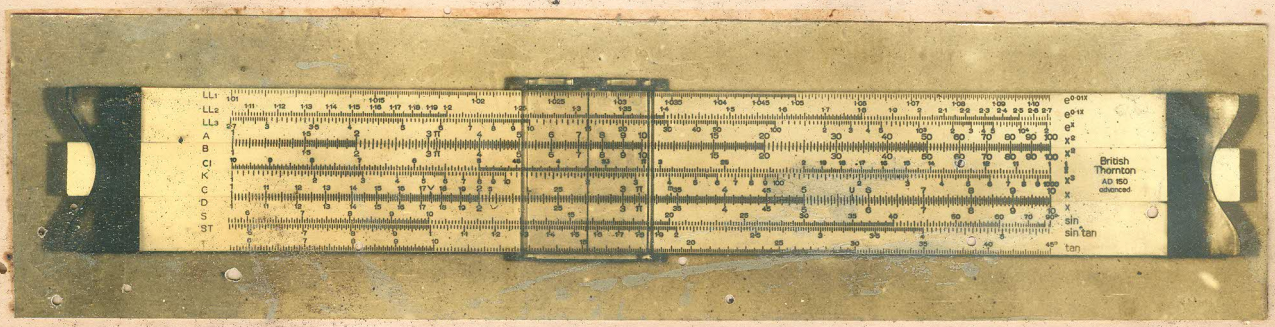
The most important slide rule scales are the C and D scales. These scales have to be placed

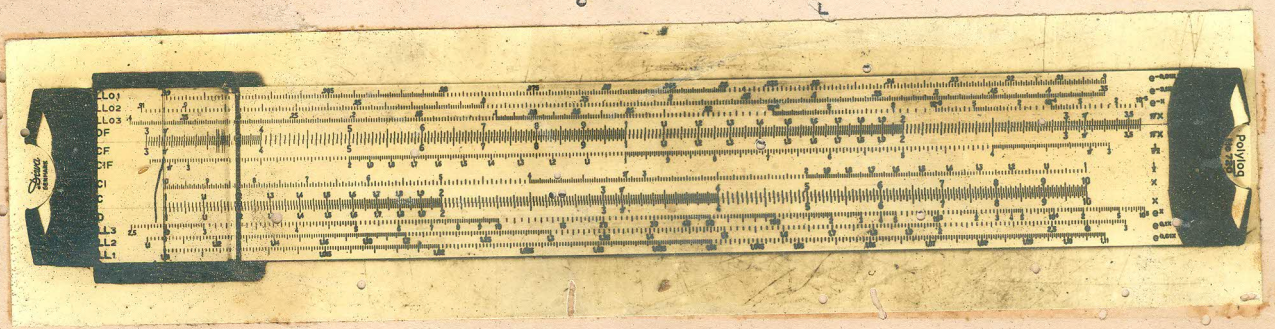


Mannheim



Duplex





opposite each other on the slide and stock resply. The other scales are placed on the stock or slide according to their functions and ease of operation. In general, a scale is so placed that it can be used with a minimum number of operations.

The choice of the scales itself is governed by the use for which the slide rule is designed. This can be a general purpose or a special purpose.

On the conventional slide rule, the logarithmic scales are

Front : DF, CF, CIF, CI, C and D

Back : K, A, B and D .

The other scales usually provided are the log-log trigonometric scales. Some special function scales are also provided sometimes. [Refer Page 10

2.6 SCALE MARKINGS

On the best slide rules, the markings are engraved and filled with ink. Conventionally two colours are used, red and black. A number of operations are required in this process. A cheaper method sometimes used is the embossing process.

2.7 SCALE NOMENCLATURE

The following terms are used to describe scale characteristics.

1. Major graduation marks: longest (or thickest) scale marks

   Intermediate : marks of intermediate length of thickness

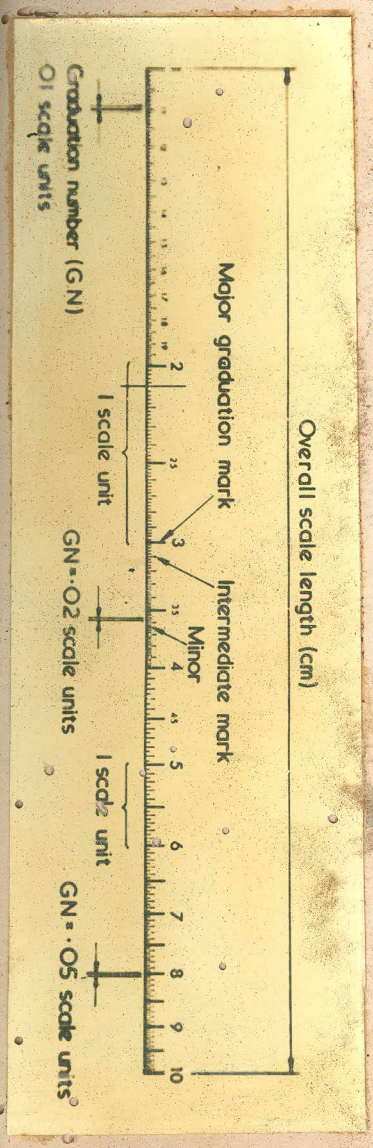
   Minor : shortest scale marks

2. Numbering system : the sequence of numbers along the scale.

3. Graduation interval : the distance (in cm, say, between two adjacent graduation marks).

4. Graduation number : the number of scale units represented by the graduation interval. (The slide rule scale is regarded as having nine units, 1 to 2, 2 to 3, etc., each being one unit).

5. Overall scale length : the distance between the lower numeral 1 and the upper numeral 1 (or 10).



2.8 USERS AND USE

The general purpose slide - rule is very widely used among the engineering students. In fact it is almost essential for every engineering student to have one. He uses it primarily for multiplication and division and for that, the C, D, CI, CIF, CF and DF scales are very frequently used.

Next in importance and frequency of use are the square scales and the trigonometric scales. The other scales are used infrequently for some special purpose calculations. (Refer Page 10)

The slide rule is quite useful to science students also for general calculations. In our country, however the slide rule hasn't found very wide acceptance among them probably due to the prohibitive cost.

The slide rule is a very handy device for businessmen and accountants. Besides multiplication and division, they can use it for some special calculations. For this purpose scales

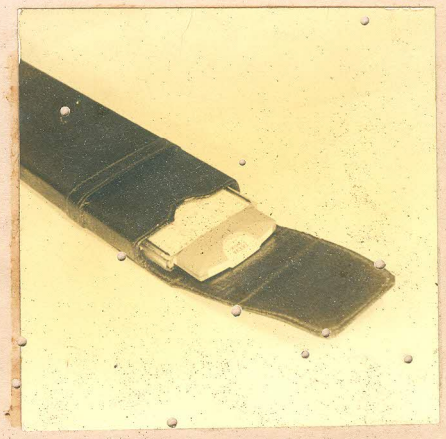
for calculation of interest etc., are provided on some slide rules. Electronic Desk Calculators are, however, replacing slide rules very fast in this area.

In some Western countries, slide rules have been adopted in schools. The school children are instructed in the use of the slide rule for multiplication and division. A few manufacturers make special models for use in schools, which are made to the same design but carry very few scales. (The Aristo Junior is one such slide rule).

2.9 STORAGE : CASES

Every slide rule is provided with a case for storage. Most of the cases fall into one of these categories

- Blow moulded plastic cases
- Leather or Foam Leather cases
- Cardboard cases, covered with rexine



2.10 PLASTIC EXTRUSIONS

Reproduced here are some extracts from two papers published by Robert Marx in Machine Design [Vol. 31,Nov.'59 and Vol. 32,March'60]

EXTRUSION MOULDING

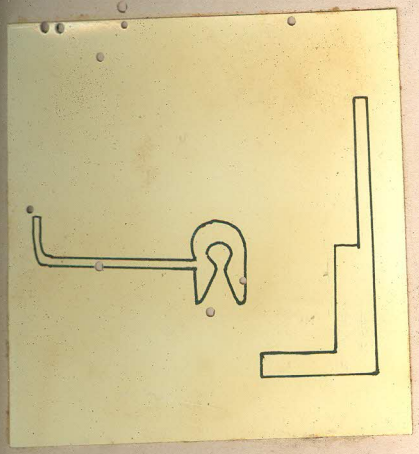
For plastic parts with uniform cross sections, extrusions are usually more economical than similar parts made by injection moulding, machining, or vacuum forming. Extrusion are specially suitable for long parts, solid or hollow. But for extremely short pieces with uniform cross-sections and thin walls, an extrusion - precision cut to length on automatic machinery-is usually easier to make than an equivalent moulded part.

Tooling costs are low. Die changes are nominal cost or free, and design changes such as flutes, beads, flanges, or sections can usually be incorporated easily into a finished extrusion die.

CHOICE OF PLASTICS

A number of plastics can be used for extrusion. The material plays a strong role in the extrudability of a particular shape. Nylon is very difficult to extrude. H.T. Polystyrene is the

easiest followed by the cellulosics and acrylic.



Where intricate cross - sections are required a shape could be extruded in rigid vinyl.

The shapes shown here in the figures were required to be extruded nylon. But nylon is difficult to extrude in such irregular shapes. In Rigid PVC however these shapes would not be difficult to extrude.

GUIDE TO EXTRUDABLE PLASTICS

H.I. Polystyrene : Low specific gravity, extremely low water - absorption. Excellent electrical properties. Good Impact Strength. Very easy to extrude.

ABS : Best known for good balance of critical properties - excellent impact strength, chemical resistance and full colour range with good surface finish. Extrusions are easily formed and fabricated.

Nylon : Tough, lightweight, low coefficient of friction, very high tensile strength. Form - stable to 400 ^{o}F. Fairly high water absorption increases impact strength. Extrudable in small - diameter rods, tubes and shapes.

Acetal Resin : Tough, rigid, with low-friction properties. Service temperature range -40 to 185 °F ; short time to 300 °F. Low moisture absorption assures good dimensional stability. Best resistance to solvents, oils, gasolines and hydrolic fluids.

Regid PVC : Combines toughness and structural strength with chemical inertness, good outdoor aging characteristics, excellent electrical properties and abrasion resistance. Hard, tough, lightweight, and non flammable. Suitable for intricate extrusions.

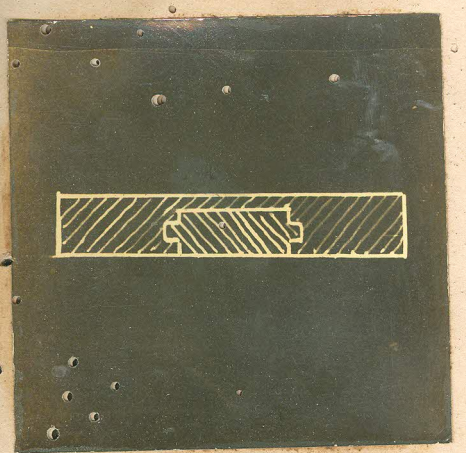
Poly propylene : Combines chemical inertness with hardness, strength, and stiffness. Lightest of all plastics. Resists distortion at temperatures to 300 °F. Broad range of colours, with attractive lustrous finish. Highly chemical resistant. Probably most economical, rigid material with widest range of desirable properties available.

3.0 ANALYSIS

The information collected from various sources is analysed here to determine the structure, mechanism and function of the various components of the slide rule. The ergonomic and economic aspects of the problem are also analysed.

3.1 STRUCTURE AND MECHANISM

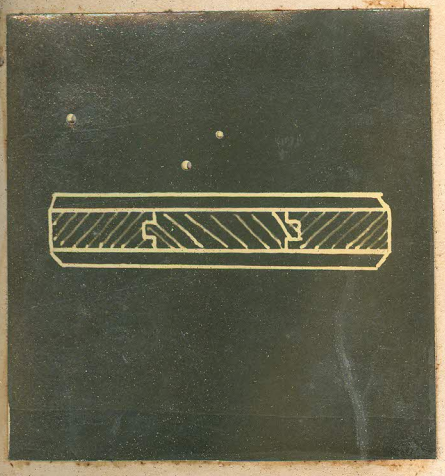
The straight slide rules [both Mannhein and Duplex] have an extremely simple structure, which is governed by the fact that the slide moves between the two outer strips of the stock. The sliding fit is achieved with two tongue and groove joints, the tongues on the slide and the grooves on the stock.



Mannheim : In the Mannheim type the stock is one piece in which the space for the slide has been formed. The stock having a solid back is quite sturdy. But the average slide is a fragile part. Its dimensions are approximately

Length	30 cm
Width	2 cm
Thickness	4 mm .

Coupled with the fact that the slide has to be moved along the length of the stock, it is quite unsuitable for any rough and careless use.



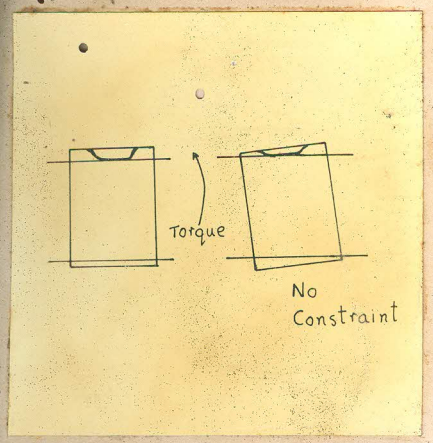
Duplex : Here the stock is formed of two strips held together by end caps. The structure is akin to a beam, fixed at the ends. It is quite weak at the centre. Dimensions of the strips are approximately

Length	30 cm
Width	1.5 - 2 cm
Thickness	4 - 5 mm .

The joints at the ends are mortise and tenon, made permanent by welding.

The basic structure of both types is such as to give two pairs of adjacent sliding scales on the same face. However, when performing simple calculations, only one pair of adjacent sliding scales is used; the other pair is redundant. Moreover the graduations on the scales have to be small to be accomodated in the small space available.

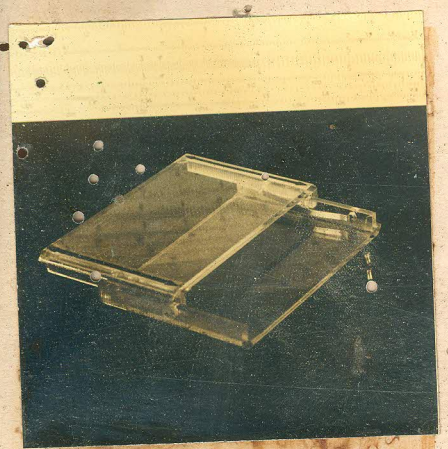
The Cursor : The cursor moves along the two edges of the stock. The movement is controlled by means of a flat-spring fastened to one of the edges of the cursor. The spring is fastened either at the centre or at the two ends.

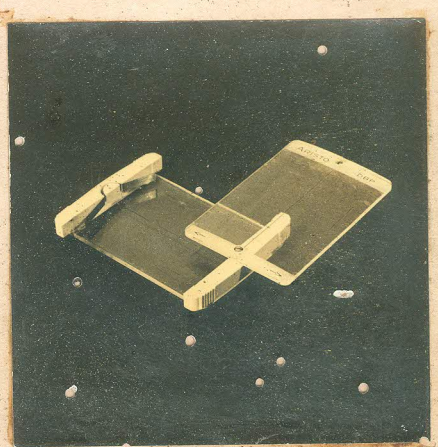


When the cursor is held between two fingers during operation a torque comes into force. If a constraint is offered to this torque there will be a twisting moment which might cause failure. The flat spring allows a certain movement thus removing that constraint.

The gap allowed for the spring should not be too much, to prevent excessive movement of the cursor around the central axis.

The torque can be reduced by reducing the distance required between the fingers to move the cursor.





3.2 FUNCTION

This is an analysis of the basic functions of the slide rule and the functions of the various parts.

3.21 FUNCTION OF THE SLIDE RULE

The conventional slide rule (engineer's slide rule) is used primarily to perform certain calculations, such as multiplication, division, raising to powers, extracting roots, etc., and various combinations of these operations. The slide rule cannot be used for addition and subtraction.

The slide rule is accurate to three significant figures. But the major reason for the use of the slide rule is the speed with which it performs routine calculations which would otherwise take a long time.

3.22 ACCURACY AND ERRORS

The conventional slide rule is useful for computing numbers to three significant figures. However, in the 1 - 2 range it is possible to go to four significant figures. Thus in

the 1 - 2 range there is no possibility of making any interpolation errors. Again in the 2 - 4 range the interpolation errors are less than in the 4 - 10 range. [The ranges mentioned are in case of the C and D scales].

Different ranges then do reduce the interpolation errors for some parts of the scale. But the use of different graduation numbers itself leads to gross errors. Another cause of gross errors is the changing numbering system.

e.g. 2.10 read as 2.05 due to different graduation numbers.

1.54 read as 1.154 due to different numbering system.

This analysis seems to suggest that some kind of a compromise is necessary between gross and interpolation errors.

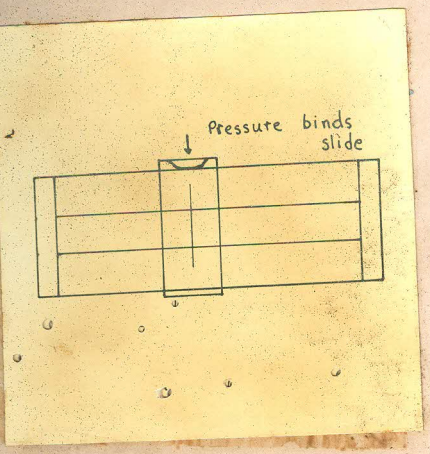
For an engineering student, who is familiar with the slide rule, it is desirable to keep the interpolation errors to a minimum because he is unlikely to make gross errors. But for

a learner in school or elsewhere gross errors can be reduced keeping interpolation errors at an acceptable level.

3.23 THE PARTS

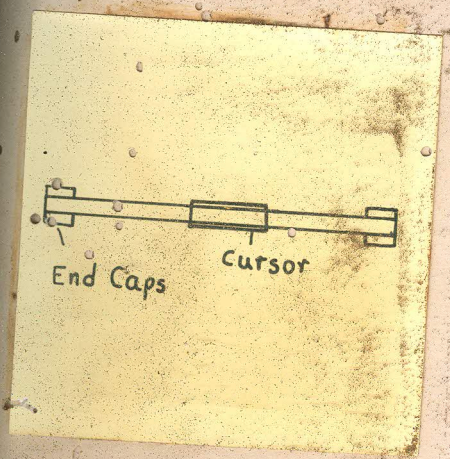
Stock and Slide : The slide should be able to move freely, but not loosely i.e., there should be good sliding fit between the tongues on the slide and the grooves on the stock.

The edges of the slide and stock should match perfectly to enable the reading of the sliding conjugate scales.



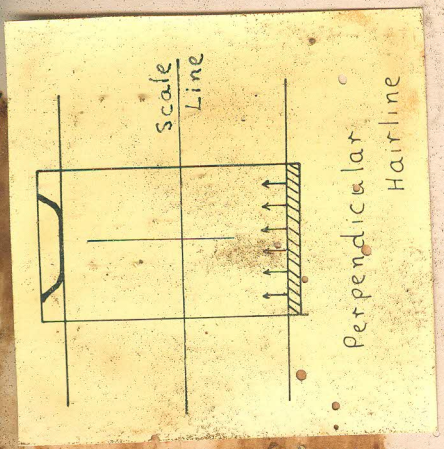
These conditions are well satisfied on the existing slide rules, except in a few cases of the Duplex where the slide is too tight. This is because of the cursor spring which exerts too much pressure, binding the slide. No such thing happens in the case of the Mannheim where the stock has a continuous rigid support, the cursor not affecting the slide in any way.

End Caps : Besides holding the stock, the end caps are required to keep the slide rule down while not in use. This is to prevent any damage to the cursor and scales.



It is therefore the practice in almost all the slide rules to give the end caps a height of about 0.5 mm to 1 mm greater than the cursor height. The actual height is probably determined by ergonomic and/or aesthetic considerations.

Cursor : The cursor should be able to move freely, but not loosely, along the entire length of the scales. At the same time, the hairline should remain perpendicular to the scale lines at all positions.



Both these conditions are ensured by the flat - spring control on existing designs. The spring is required to exert an optimum pressure to enable a sliding motion. The spring also holds the lower edge of the cursor flat against the lower edge of the stock, thus keeping the hairlines perpendicular.

The cursor on a conventional slide rule has been designed to perform the following functions, the first three of which are vital.

1) to locate a graduation (or interpolated graduation) by means of a hairline.

2) to align conjugate graduations on two or more scales on one or both faces of the slide rule.

3) to hold the position of a graduation while the slide is moved to another setting.

4) to reduce slide movements to a minimum by means of auxiliary hairlines.

Some cursors employ magnifiers for help in reading the scales. Some have the glass shaped in the form of a lens.

The magnifier definitely helps in reading but as it covers a small area, that area gets distorted in size with respect to the rest of the scale. It sometimes becomes difficult to judge the graduation number of a graduation interval.

3.3 ERGONOMIC

In this section, the ergonomic aspects of working with slide rule are discussed. Also included is an ergonomic analysis of the scales.

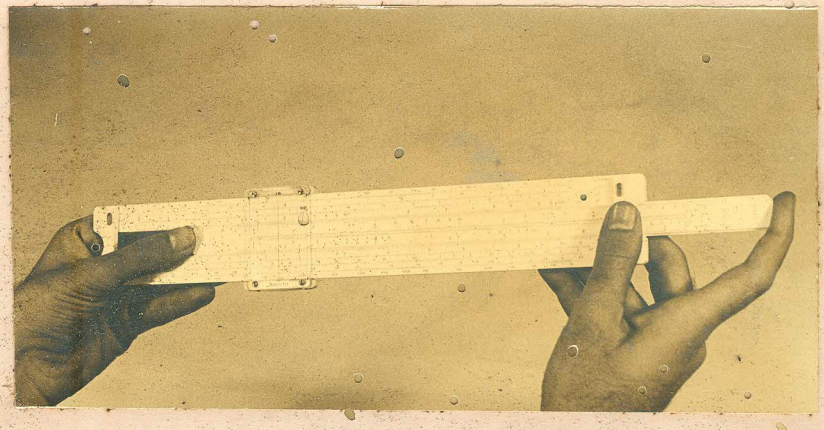
3.31 HOLDING THE SLIDE RULE

In the Mannheim type it is permissible to hold the stock in the hands at any position without impeding slide movement. But the Duplex has to be held carefully at the ends as a slight pressure on the outer strips is sufficient to bind the slide.

3.32 SLIDE RULE MANIPULATION

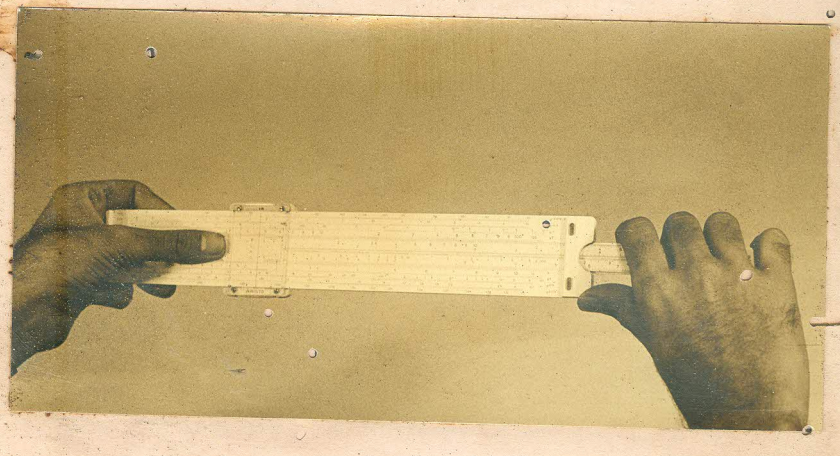
Accurate setting of the slide can be achieved easily by using two hands, but not with one. There are a lot of variations in the manipulation of hands in setting the slide. The general procedure is outlined here.

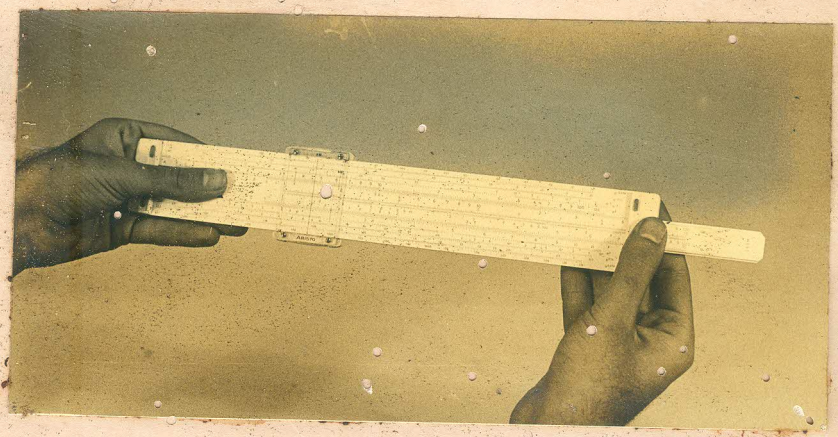
The slide is pulled or pushed with either hand into the neighbourhood of the desired setting.

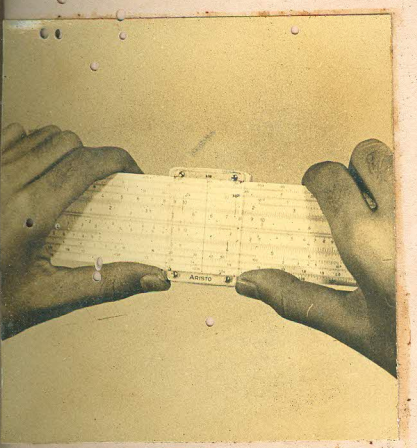


For the final setting, counterpressures are applied at each end with the forefingers or with thumb and forefinger. If the slide projects too far to the right for the right forefinger to reach the right end, the slide is grasped with the right thumb on top and right forefinger underneath.

No one procedure can be said to be the most efficient. But it can be said with certainty that the slide can be set best by using counterpressures applied simultaneously at each end.







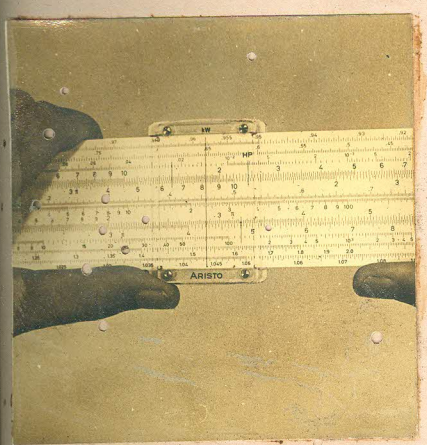
The slide has to be moved sometimes over quite large distances to extreme positions and it becomes difficult to reach your fingers where they are required. This problem is in the case of 25 cm base slide rule, but not in the case of the 12.5 cm base.

3.33 CURSOR MANIPULATION

Cursor setting is done in a manner quite similar to the one used for setting the slide. The principle of counterpressures is useful here also however the cursor can be set using both hands or only one. The one handed method is the more common one.

. The cursor is moved to the neighbourhood of the setting with the thumb and forefinger.

. The final setting is made by letting the thumb rest lightly against both the cursor and the lower frame.



No particular difficulty is encountered in this process.

3.34 SLIDE RULE SCALES

A slide rule has many complicated scales. The large number of scales engraved on a small space tend to give a crowded appearance to the face of slide rule.

The requirements of the various operations and accuracy does not allow an adherence to the general principles of scale design regarding the numbers and size of scale graduation marks, the numbering systems used and the size of the numerals and letters.

The slide rule scales are ~~made~~ rather difficult to read because of the fact that they are non-linear. On the C,D and other logarithmic scales the principle difficulties are in the progressive changes in the graduation number, the number of graduation marks, changes in the numbering system along the scale and the large number of graduation marks. This is particularly difficult at the upper end of the scale.

3.4 ECONOMIC ANALYSIS

The economic aspects of the problem are analysed here in relation to the conditions existing in our country.

There is only one slide rule manufacturer, Deeva Pvt. Ltd.*, in our country who have any reputation. They produce two models both of which cost about Rs.90.00 . However, slide rules are still imported and these imported ones cost in the range of Rs.100 - 250.

It is probably the high cost of these slide rules which has prevented their use on a wider scale. Although it could be useful to a wide range of students and others, it is used mainly by the engineering students for whom it is absolutely essential.

The cost of production is actually not very high, but is still quite considerable. The Deeva slide rule for instance is quite costly to make [about Rs.50 - 60] because of the following processes

1) The stocks and slide are machined separately and then assembled. The assembly is a process requiring considerable skill because the graduations have

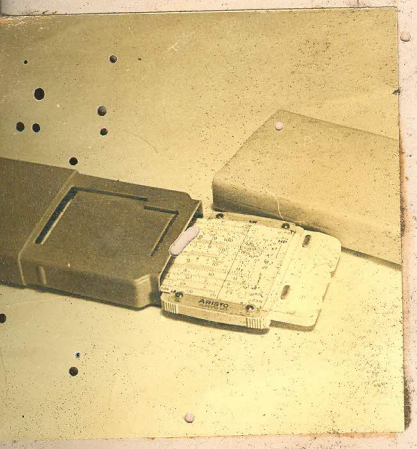
to be matched.

2) The markings are engraved and then filled with ink. This is done in two colours. The engraving die has to be imported and is therefore very expensive.

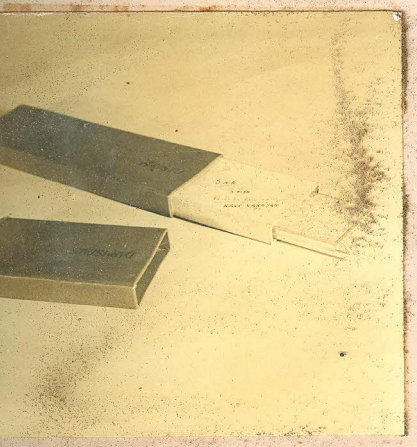
The material used, PVC and the other injection moulded components [end - caps and cursor] do not cost much. [About 10% of the total cost.

* Deeva Pvt. Ltd.
Tardeo Air-Conditioned Market
Bombay

3.5 ANALYSIS OF THE CASE

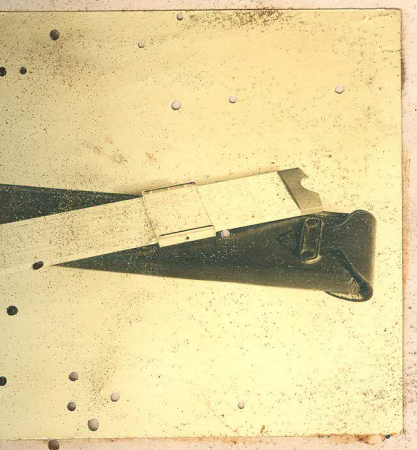


In the blow moulded type of case, a great attention is paid to the details to facilitate the insertion and removal of slide rule. The case is in two pieces with one fitting over the other. The cardboard cases are also generally of this type.



The leather and other cases have a flap at the end. In these cases, there is no separate provision for the cursor with the result that the slide rule gets stuck sometimes and there is a possibility of damage to the cursor.

In most of these storage cases there is no provision for carrying the slide rule while on the move. It is generally held in the hand along with the books, etc., by students.



Separate leather cases are available with a strap to hang over the shoulder, which are provided by the dealers. These leather cases carry the slide rule along with its original case. This gives a rather monstrous size to the comparatively small slide rule.

3.6 THE CIRCULAR SLIDE RULE : An Analysis

The circular slide rule functions like the straight slide rule. But the scales are continuous, and therefore there is no need to reset as in the straight type i.e., bring the slide back to position after operation.

The disc calculators can be quite compact; and in some cases quite inexpensive.

There is however a major drawback in this design . The graduations lie in a circle at varying angles to the eye which therefore has to travel in circles when reading the scales. This not only makes it difficult to read but may also cause eyestrain with continuous use for lengthy periods.

4.0 HYPOTHESIS

After analysing the existing conventional slide rules and determining the requirements of the desired solution, the problem is examined here again.

Stock and Slide : If the slide rule is to be used by schoolchildren, it is likely to be subjected to rough use. Therefore, the slide rule should have a sturdy construction.

It would be unreasonable to expect the school student to hold the slide rule in one particular manner. The requirement then is that it should be possible to hold the slide rule in any convenient manner. There might still be more efficient ways of holding it, but any variation from those should not effect the basic operations.

The new slide rule will be principally used for division and multiplication. The scales provided will therefore be such that these basic operations can be carried out with ease.

Too many scales are not required here, as their use, if at all they are used, will be

very rare. Therefore to reduce the confusion and present a comprehensible graphic layout, the scales will be reduced to the minimum.

Scales : There will be only one pair of adjacent sliding conjugate scales, C and D. There may also be some fixed conjugate scales.

In the design of the scales themselves, the recommendations given in the texts will be followed as far as possible. Some studies have been published[2] concerning the design of slide rule scales for schoolchildren. The solutions and recommendations offered in these studies will be considered in the new design.

Cursor : In the design of the cursor, it is imperitive to ensure that the cursor performs its vital functions. The provision of auxiliary hairlines indicating constants might not be necessary here and in fact, may be quite undesirable to avoid confusion.

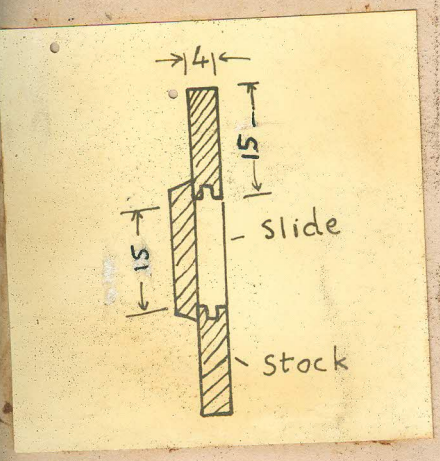
Case : The slide rule should have a case for storage. The case need not be a sophisticated moulded one. It can be made from foam leather or cardboard covered with rexine.

There should be a provision for the cursor to fit in easily. Insertion and removal of the slide rule should be fairly easy.

If possible some means of carrying it while on the move should be provided. This could be a strap or clip.

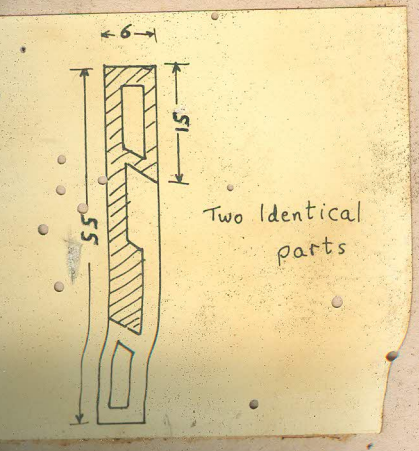
5.0 DESIGN

A number of possibilities for the final solution were examined, some of which are presented here very briefly.



First Alternative : This is a modification of the conventional Mannheim type of slide rule, with a solid back to the stock. The stock can be held at any position. The scale length is 12.5 cm, to give a slide rule size which can be handled easily even with small hands and is handy to store and carry.

It is to be injection moulded . There will be separate moulds for the stock and the slide. For ease of moulding the stock has been given a section to make the wall thicknesses uniform. The back side is therefore, not flat.



Second Alternative : Here the slide rule is made in two identical parts with one part sliding over the other.

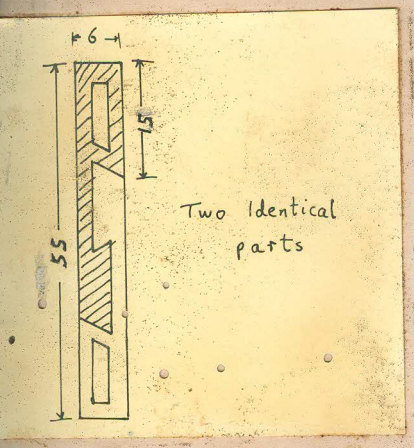
This design provides for two pairs of adjacent sliding scales, one on each side. The two

identical parts have been given to reduce the cost of manufacture. It is to be injection - moulded.

The sliding joints are such that there is no undercut in the mould. The joints hold the two parts together perfectly in only one direction. The cursor has to perform the function the holding the parts together also.

The size chosen is the 12.5 cm scale here also.

Third Alternative : This design is derived from the previous one. It has two identical parts. But the sections have been designed for extrusion or injection moulding.



Dovetail joints are provided for the sliding fit, which are sufficient to hold the two parts together. A groove is provided for the cursor.

The size chosen is again the same with the 12.5 cm scale length on the basic decade.

[Details are described in the drawings and the following pages.]

5.1 BASIC FORM

The basic form chosen is that having two identical parts, one sliding over the other (Third alternative). The form is evolved from the conventional form in the following manner.

1. The conventional form has a slide moving in the stock offering two pairs of adjacent sliding scales. In accordance with the present design requirements only one sliding scale is required.

2. A typical face of a slide rule has the following scales :

   Upper stock : $K(x^3)$, etc., and $A(x^2)$

   Slide : $B(x^2)$, $CI(1/x)$, $C(x)$.

   Lower stock : $D(x)$, S.T., etc.

For the present problem only the scales necessary for basic operations [multiplication, division, squares and square roots, and combinations of these] are required.

Three scales are provided on the conventional slide which is about 1.5 cm - 2 cm wide. For the scales to be spaced out for ease in reading,

the slide will have to be much wider [about 3 cm], increasing the total width of the slide rule.

These two requirements lead to the present form which can be considered, in terms of conventional designs, to consist of

1. lower stock
2. expanded slide.

It can be argued that the requirement of one pair of adjacent sliding scales is no constraint, since having two will do no harm. But having the second pair will actually draw the user's attention towards it. It is desirable that there be no distraction from the fundamental pair of adjacent sliding scales.

The form also offers an advantage for manufacture. It is in two identical parts and therefore reduces mould costs, whether it is injection or extrusion moulded.

In the final section details, care has been taken to see that wall thicknesses are kept uniform as far as possible to facilitate moulding.

5.2 THE CURSOR

The cursor is designed for injection moulding in acrylic. The spring will be supported at the centre. There is no need for fastening the spring.

The cursor is supported at only one end and is therefore akin to a cantilever. The shape is such as to reduce the weight towards the top end [actual weight and visual weight].

5.3 STOPS

Stops have been provided on the face of the slide in the groove for stopping the cursor and the slide a little beyond the extreme positions.

The stops on the face are also used to rest the slide rule when not in use. Their height is about 0.5 mm more than that of the cursor for this purpose.

The stops on the groove for the cursor don't cover the entire width of the groove but only half of it. This facilitates removal of the cursor when it is required.

5.4 ERGONOMICS : USE

The slide rule can be held at any position. The stock can be grasped with the thumb at the top and fingers underneath or can be held resting on the palm.

Setting the Slide : The principle of counter pressures is used here also for efficient setting of the slide. There is no problem of the reach of the fingers in this case. The general procedure may be

. The slide is moved into the neighbourhood of the desired setting by pulling or pushing. For this, one can hold one end of the slide between thumb and forefinger, or rest the forefinger on the top edge and grasp between thumb and middle finger.

. For the final setting the slide can be moved in the manner described above and the counterpressure applied by the thumb resting on both stock and slide with the fingers underneath, or

. The conventional manner in which thumbs and forefingers are used can be used to set the slide.

Setting the cursor : The final setting of the cursor is also done by applying counterpressures. The two-handed or the one-handed method can be used.

When setting the cursor by using thumb and forefinger, the torque is reduced because the distance between the thumb and forefinger is less than in the usual case.

5.5 SCALES : Graphic Layout and Ergonomics

The scales have been arranged spaciously to present an easily comprehensible graphic layout.

The scales themselves have been designed with a constant graduation number. It is not possible in non-linear scales to have both graduation numbers and graduation interval constant. A constant graduation number would facilitate comprehension. This would reduce gross errors, with a slight increase interpolation errors thus sacrificing some accuracy.

There are no numerals on the intermediate marks, for simplicity. Also, they are of no help in reading.

The sizes of the marks and numerals have been

chosen in a way that they can be read easily.

The process uses for printing can be hot embossing, which is not very expensive. However, the desired accuracy of printing may be difficult to attain.

Plastic coated paper can be used which is stuck on the face. Steps have been provided to fit the paper in.

5.6 THE CASE

The case is to be made in foam leather or PVC cloth. The cursor fits into the space provided for it at the top.

A clip is to be provided so that the case can be clipped on, to the trouser belt, trouser pocket or even shirt pocket.

Note : There is some difference in the designs for injection and extrusion moulding. and [The sections are identical].

In case of extrusion, the stops on the face and groove are to be separately injection moulded and then welded.

In injection moulding the material used will be ABS, while extrusion will be in PVC.

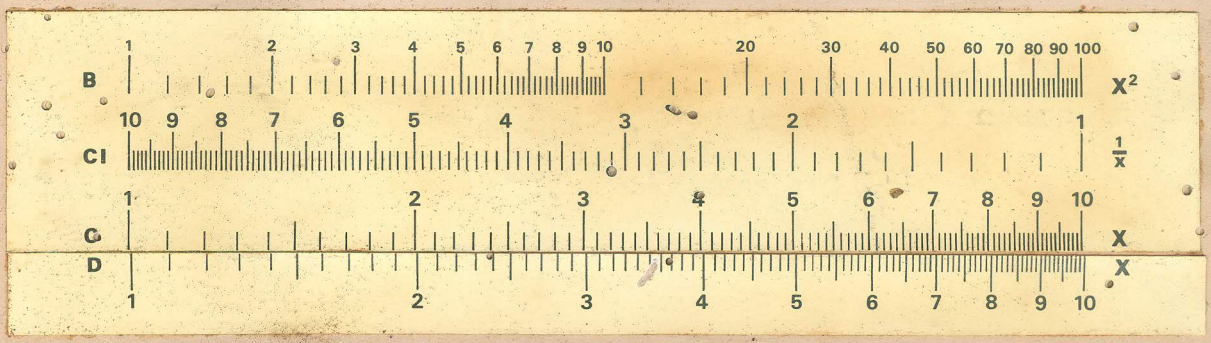
Although it has been said that the two parts are identical, they are not exactly identical. There is an additional groove on the stock. A slight change will have to be incorporated in the die for moulding.

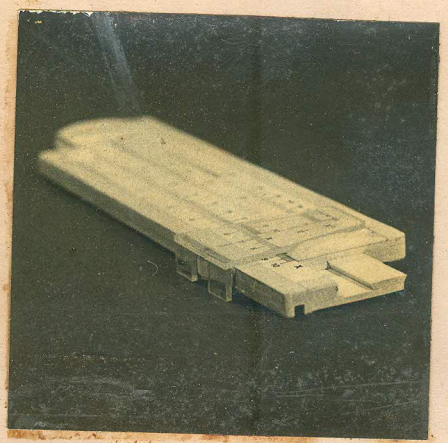
In injection moulding, the undercut dovetail section will be provided by means of a hydraulically operated side core. The hollow portion is obtained by means of a separate part, which is to be inserted after moulding. (Refer the drawings)

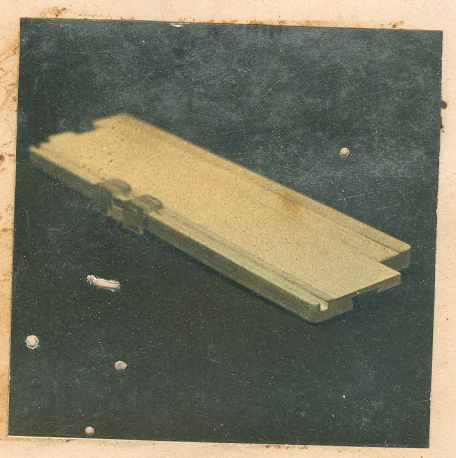
All the parts - stock, slide and the two parts for making the hollow sections will be moulded in the same die.

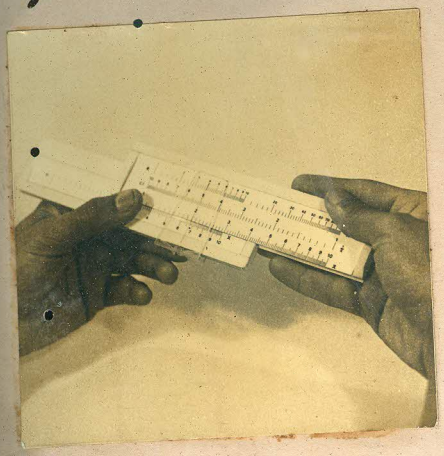
ABS has been chosen for its balance of critical properties - strength, dimensional stability and ease of moulding.

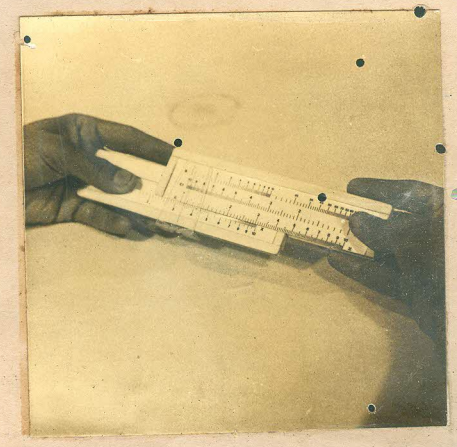
For extrusion, PVC is chosen because it is fairly easy to extrude this particular section in it. Besides it has the required strength and good abrasion resistance.

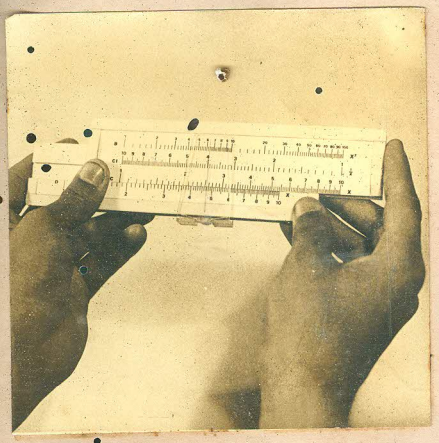


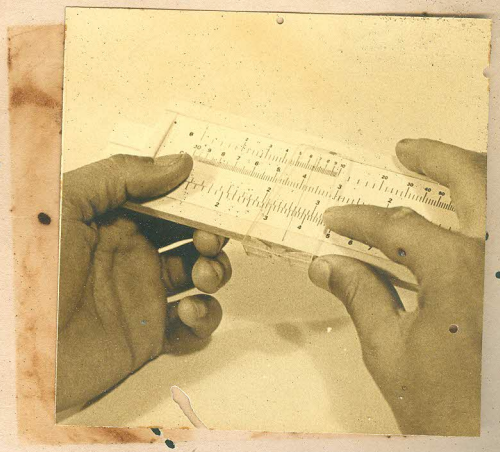


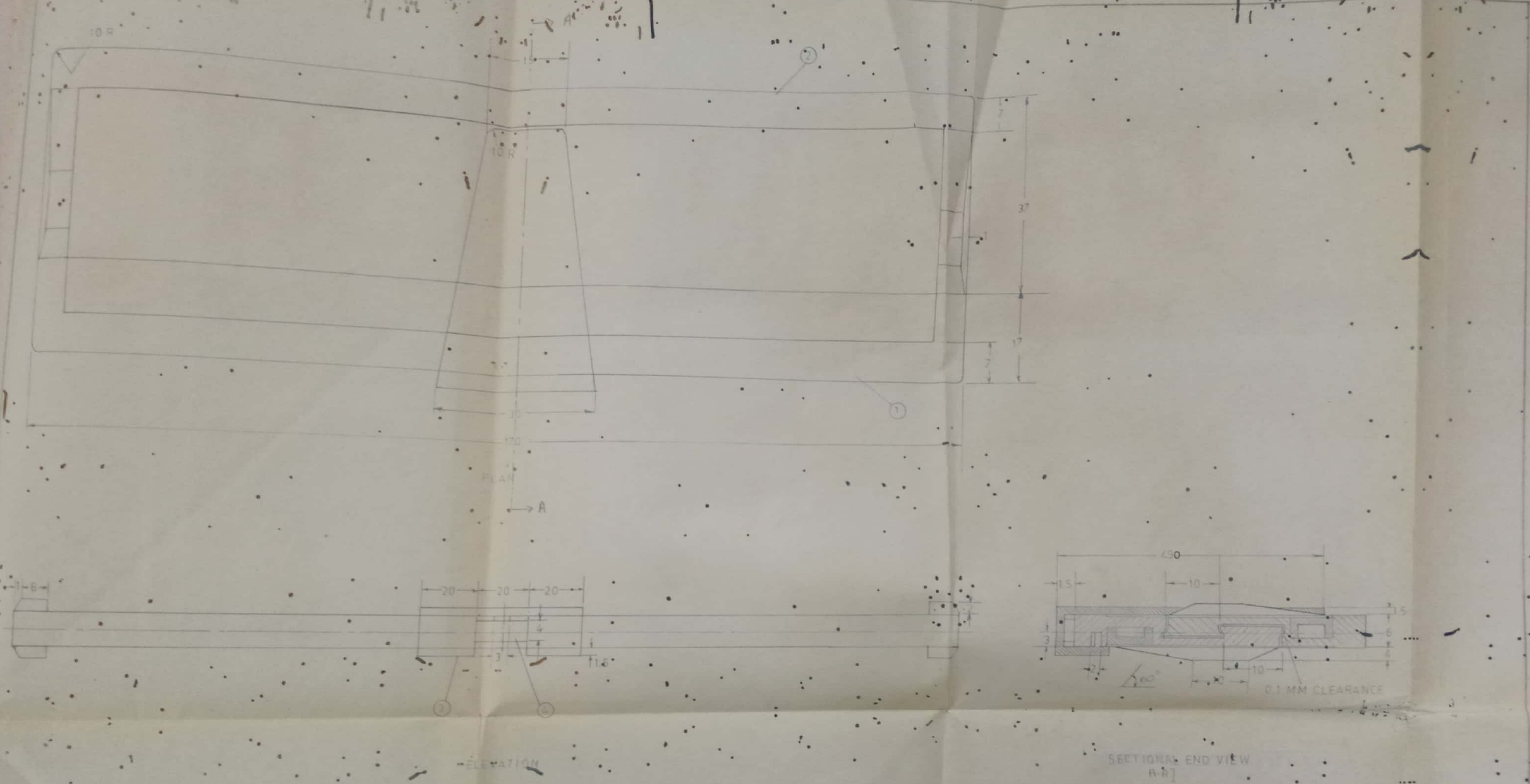












NO	DESCRIPTION	MATERIAL	PIECES
4	FLAT SPRING	SPRING STEEL	1
3	CURSOR	INJECTION MOULDED ACRYLIC	1
2	SLIDE	INJECTION MOULDED ABS	1
1	STOCK	INJECTION MOULDED ABS	1

DIPLOMA PROJECT : SLIDE RULE FOR SCHOOL CHILDREN

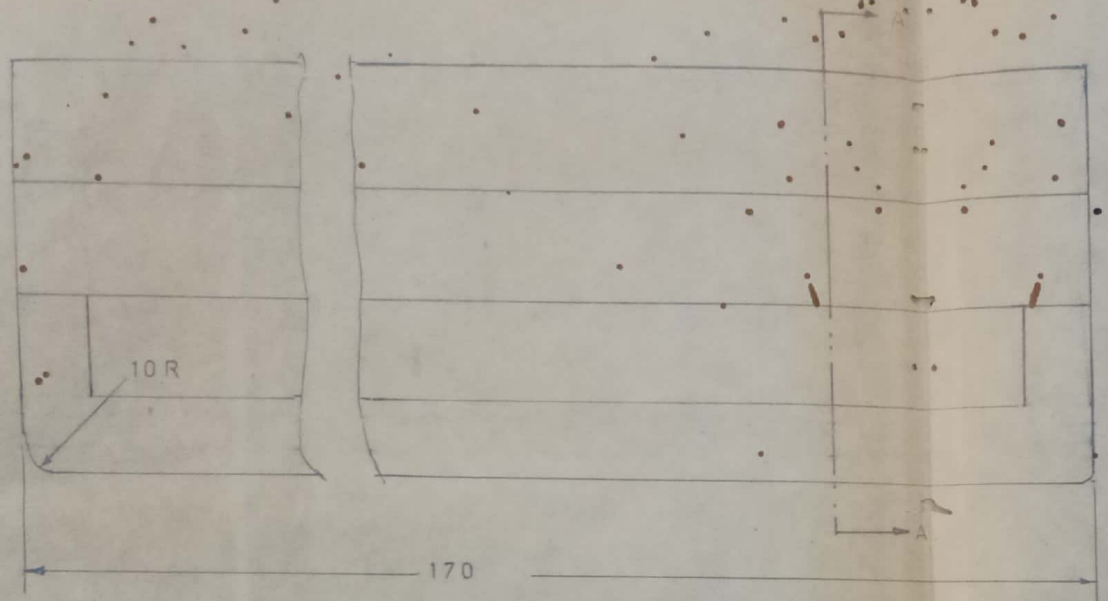
ASSEMBLY

TWICE SIZE

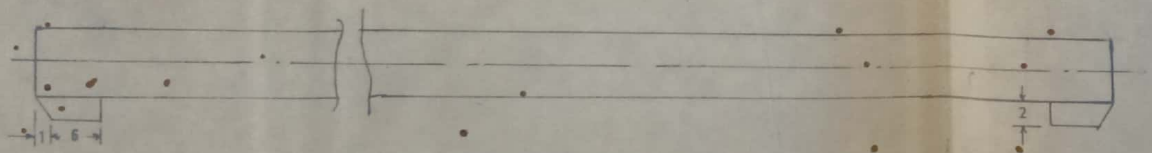
DIMENSIONS IN MM

DRG. NO 1

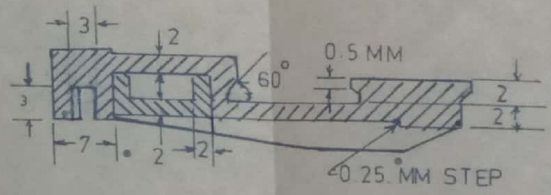
INDUSTRIAL DESIGN CENTRE I.I.T. BOMBAY



PLAN



ELEVATION



SECTION AA

DIPLOMA PROJECT: SLIDE RULE FOR SCHOOL CHILDREN

STOCK

S. R. GURSAHANI

ROLL NO. 732704 | 73-75 BATCH.

TWICE SIZE

DIMENSIONS IN MM

DRG NO 2

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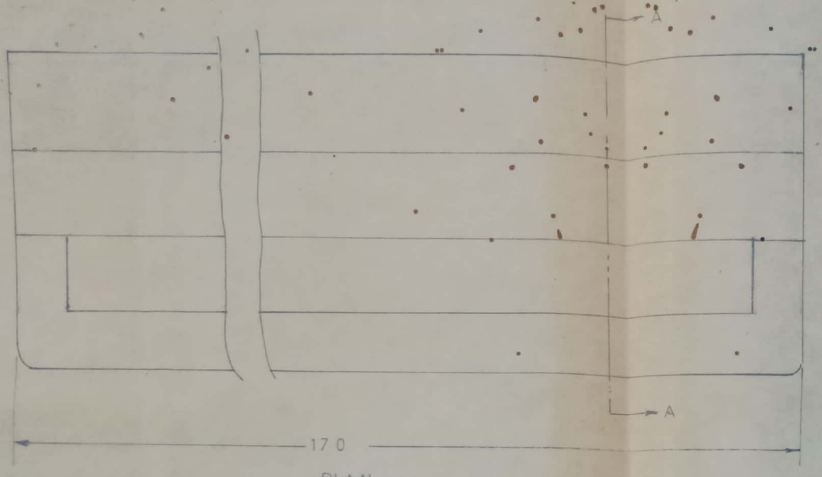

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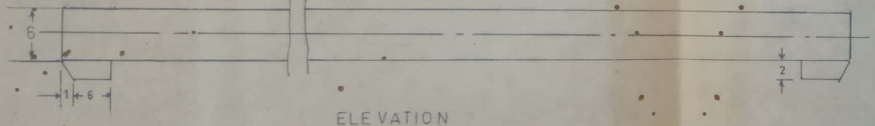
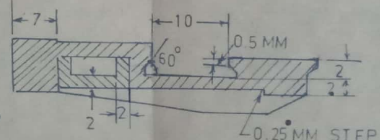


ELEVATION

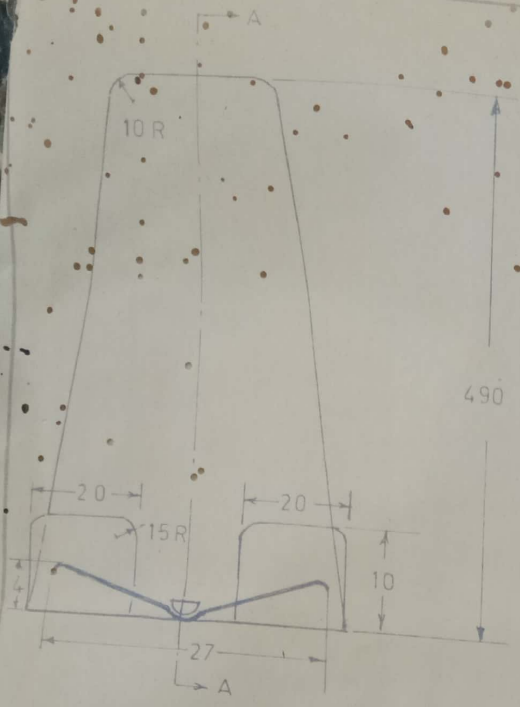


SECTION AA

DIPLOMA PROJECT : SLIDE RULE FOR SCHOOL CHILDREN

SLIDE	S.R. GURSAHANI
	ROLL NO. 732704 | 73-75 BATCH
TWICE SIZE	DRG NO 3
DIMENSIONS IN MM	

INDUSTRIAL DESIGN CENTRE, I.I.T. BOMBAY



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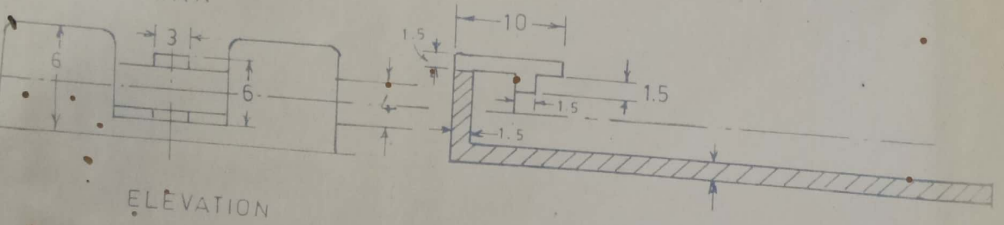


ELEVATION

SECTION AA

DIPLOMA PROJECT: SLIDE RULE FOR SCHOOL CHILDREN

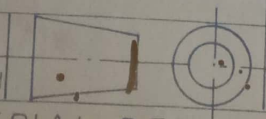
CURSOR

S. R. GURSAHANI

ROLL NO. 732704 | 73-75 BATCH

TWICE SIZE

DIMENSIONS IN MM



DRG NO 4

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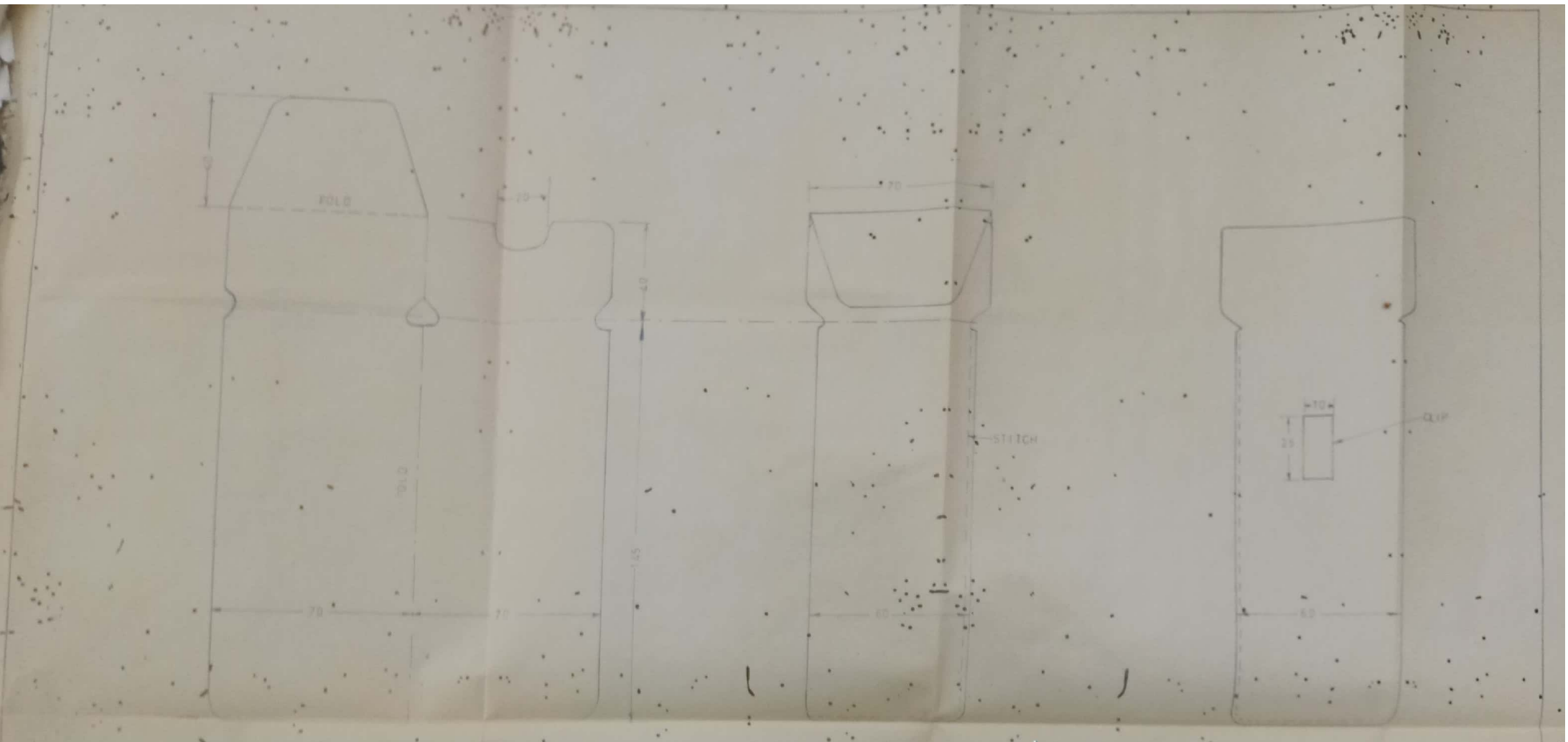

NO	DESCRIPTION	MATERIAL	PIECES
1	SLIDE RULE CASE	FOAM LEATHER	1

DIPLOMA PROJECT: SLIDE RULE FOR SCHOOL CHILDREN

CASE

S. R. GUNSAHANI

ROLL NO. 72702 | 72-73 BATCH

DRG NO. 5

INDUSTRIAL DESIGN CENTRE, I.I.T. BOMBAY

REFERENCES

1. K.F.H. Murrell : 'Ergonomics'
Chapman and Hall, 1969.

2. R.J.Talbot
R.Roy : 'Applied Ergonomics'
Vol.3, No.3, 1972.

'Ergonomics'
Vol.14, No.4, 1971.

3. Lee H. Johnson : 'The Slide Rule'
Van Nostrand, 1949.

4. J.N. Arnold : 'The Slide Rule'
Prentice-Hall, 1954.

5. R.K.Allan : 'Systematic Slide Rule Technique'
Pitman, 1962.