

**REPORT ON DESIGN OF TRANSPORT
SYSTEM FOR LAME PERSONS**

Diploma Project

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**INDUSTRIAL DESIGN CENTRE
INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY
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Report on design of transport

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b a. poovaiah

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Transportation System for Lame Persons (Crutches)

Diploma Project

Submitted in partial fulfilment of the requirements
for the postgraduate diploma in Industrial Design

by

B.A. Poovaiah

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1. INTRODUCTION

1.1 What is handicap?

Handicap is a defect representing a decrease in or loss of ability to perform various functions particularly those of musculoskeletal system and sense organs.

1.2 How much handicapped are they?

We suffer from a world designed for the normal man and woman. In addition, many parts of our man-made environment were not designed for any person at all but merely engineered down through time by new materials and methods. Architects, designers and planners have taken advantage of the apparently unlimited ability of the human being to tolerate discomfort and inconvenience. The concept of fitting the activity of the equipment to meet the needs of the human being rather than vice versa, is not very much applied anywhere, particularly so in India.

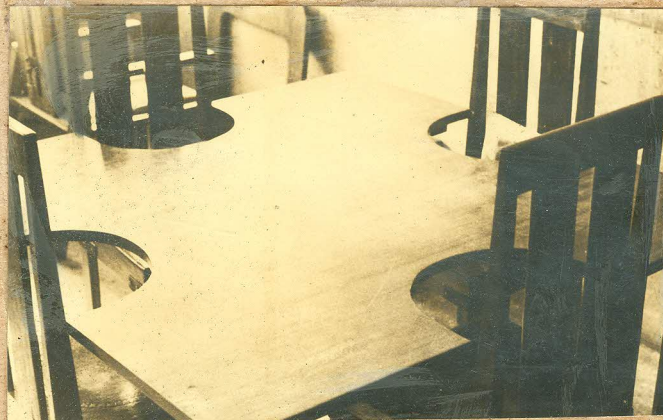
Apart from the physical environment, a man has an emotional world of his own. But here too society demands its share in his thinking and feelings in order to adjust with his fellow beings.

To the handicapped persons, the man-made environment and involvement with the society for confirming with

"The more the handicapped become incorporated into the existing community the less visible as a separate group they will become. This requires an understanding of the built in barriers around us that can be removed to the benefit of all of us." —Policy statement issued at the special session on welfare at ICSID '73, in Kyoto, Japan.



"The knobs on most tv's, for example, although the same could be said for other products and appliances, are frequently small and difficult to grasp. In addition, their placement which is usually recessed compounds the problem."



a well designed

childrens furniture

"The greatest hurdle is to convince the operators and manufacturers of mass transportation vehicles that by meeting the needs of the handicapped they will be providing a superior, safer, and more convenient service for everyone."



the normal, present formidable barriers. These barriers make it very difficult to project them into normal situations of education, recreation and employment. To the physically disabled individual, influenced by a society that holds productive activity and personal autonomy in esteem, it can mean a life of loneliness, self criticism and despair.

1.3 Major need of the handicapped

The handicapped person has to adjust to his personal need and that of the community overcoming his physical disability. This would require him to perform normal activities which are impeded because of his handicap. Thus he requires to use some external device or aid to improve his physical disability. Although, the extent to which he could adjust with the normal depends on him and his environment.

2. HANDICAPPED - TRANSPORTATION

An easy 'mode of transport for the lame person' is conceptualised in this report.

An external aid or device is essential for the mobility of a lame person. This would help him in acquiring more personal freedom and improving his physical functions.

The number of lame persons exceed 7 million in our country. This denotes the gravity of the situation.

The major portion of these disabled come from severely poor economic conditions. Hence what they can afford to invest ⁱⁿ and maintain an external device is also a bare minimum.

This means that a large number of these persons have to be rehabilitated into situations of earning their own livelihood and leading an autonomous life.

3. TYPES OF LAMENESS

Lameness can either be temporary or permanent.

Temporary lame persons are those who suffer temporary physical disability of the lower limbs. This may be due to

- sickness
- injury
- fracture or sprain
- fatigue

Permanent lame persons are those who have chronic or permanent defect or ailment in which the lower limbs are affected. This may be due to

- cerebral palsies - spasticity, ataxia, rigidity, tremor
- arthritis
- amputation
- old age

Depending on the type of lameness and the extent to which they are affected, the lame persons can be classified as groups able to

- stand and walk without external device
- stand and walk with external device
- cannot stand and walk

Information

Paraplegia :

Paraplegia is paralysis of the lower part of the body involving both legs and the trunk below the level of the lesion. The paralysis is due to injury or disease of the spinal cord or cauda equina. Injuries which produce paraplegia are usually severe compression fractures or fracture dislocation.

Amputation :

Amputation is surgical removal of a part of or an entire limb either upper or lower extremity. Various reasons for amputation are injury, infection, tumour, diabetics or insufficient blood supply. Occasionally amputation is also performed on non-functioning or grotesquely deformed limbs.

Cerebral palsy :

This may arise from any condition producing a brain lesion resulting in a motor disability.

Arthritis :

This is a disease or disability in which there is inflammation in a joint. This is chronic, generally progressive disease.

4. PRESENT TRANSPORTATION SYSTEMS

Various types of external devices used for mobility of the lame person at present are

- . wheel chairs
- . three wheelers
- . artificial limbs
- . knee calipers
- . crutches

4.1 Wheel chairs

Wheel chairs are used by persons who have a lot of difficulty in supporting themselves.

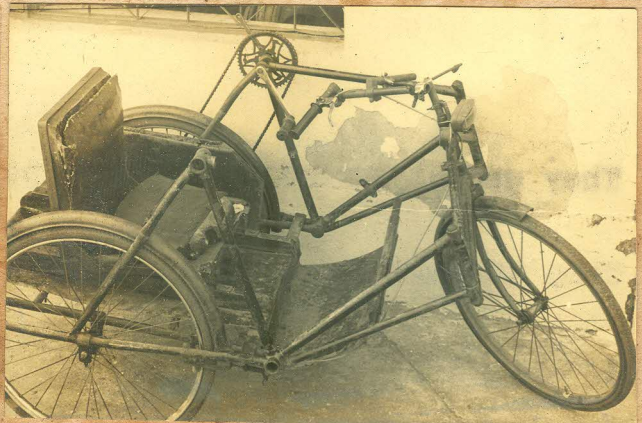
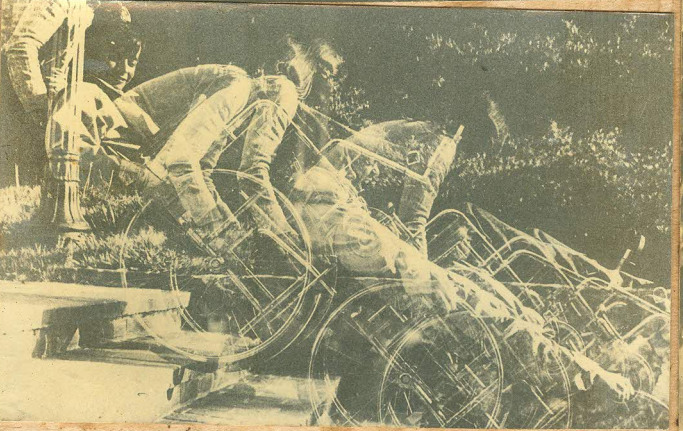
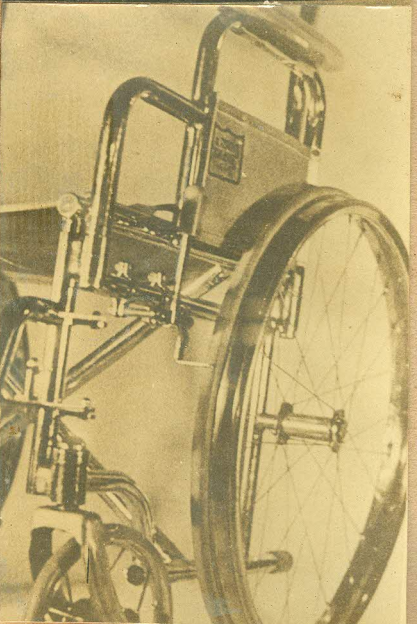
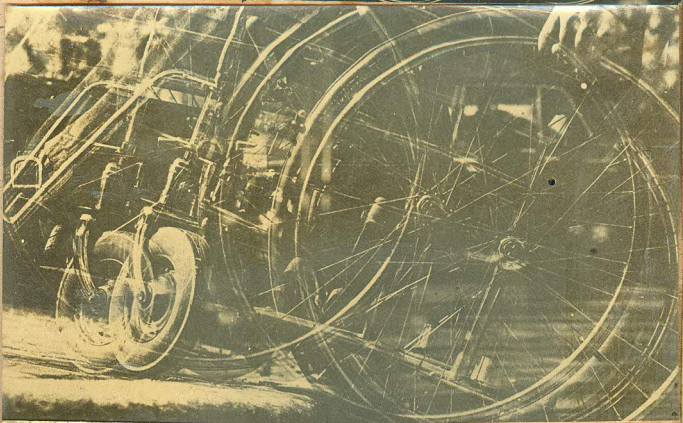
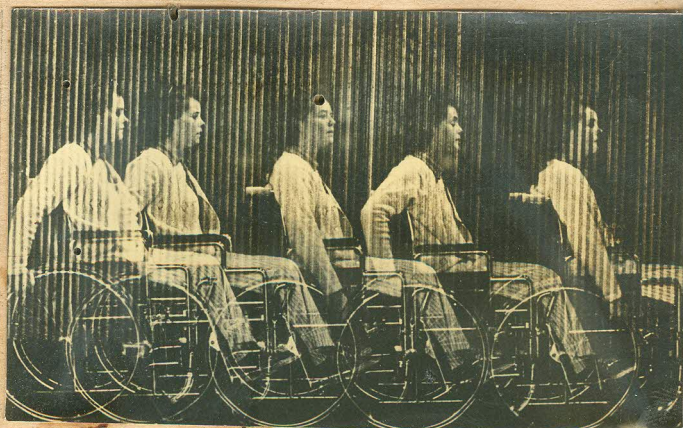
Wheel chairs are meant for indoor use and need flat surface and enough space for movement. The wheel chair user is in a comfortable position (sitting). The speed of travel is slow. The major problem with the wheel chair is that they cannot go up or down stairs.

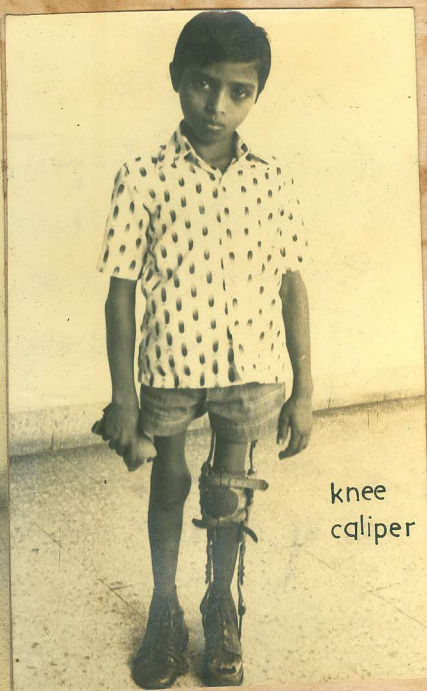
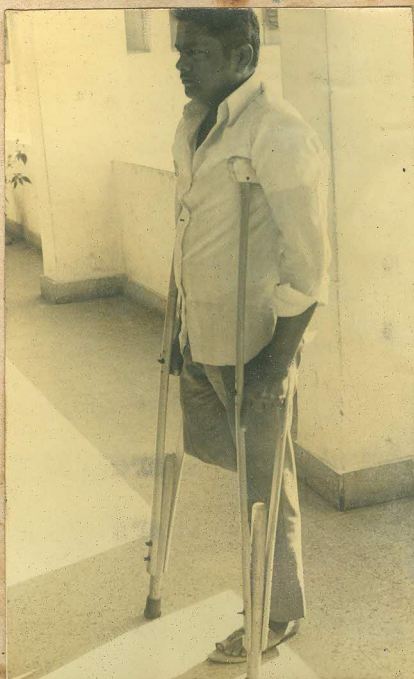
Wheel chairs are expensive.

4.2 Three wheelers

Three wheeler offer a transportation system equivalent to that of a bicycle for lame persons.

These are used outdoors but they cannot go over steep inclines and uneven roads. The user has to use some other device when he disembarks the tricycle.





They cannot be driven by weak persons.

They require lot of investment and maintenance.

4.3 Artificial limbs

These are used by amputees. These are ideal for amputees since artificial limbs can serve as an other normal leg. But double amputees would have to use some other device for aid while walking.

These require considerable investment and maintenance.

4.4 Knee calipers

Knee calipers are used to make the paralysed leg more rigid and stronger. These would have to be used by patients with weak leg muscles. The patients might need some other device while walking.

4.5 Crutches

Crutches are mostly used by paraplegic patients. Other lame persons also make use of them. Crutches are versatile. They can be used both indoors and outdoors. They can be helpful in going up or down slopes. The speed of travel is equivalent to walking. The user cannot use it over long distance. It helps in exercising their muscles. The user occasionally suffers from sores at contact points.

Investment and maintenance is very low.

4.6 Conclusion

From the analysis of the above modes of transport crutches are more versatile and can be used by maximum number of lame persons. These would require minimum investment and hence would suit the Indian conditions, where majority of the physically handicapped are poor.

Information

Wheel chairs - classifications

Power

- . One hand operated wheel chair
- . Two hand operated wheel chair
- . Motorised wheel chair

Compactness

- . Rigid wheel chair
- . Foldable wheel chair

Wheels

- . Back wheel drive wheel chair
- . Front wheel drive wheel chair

Drive

- . Hand operated wheel chair
- . Rotary type with belt or chain drive wheel chair
- . Push and pull type wheel chair

Three wheeler - classifications

- . One hand propelled, cost - Rs. 800/-
- . Two hand propelled, cost - Rs. 850/-
- . Motorised, cost - Rs. 2,800/-
- . Push and pull type, cost - Rs. 1,350/-

5. CRUTCHES

Various types of crutches used by lame persons are

- . stick as ^σcrutch
 ^
- . auxillary crutches (shoulder crutches)
- . forearm crutches (Canadian crutches)

5.1 Stick as ^σcrutch ^

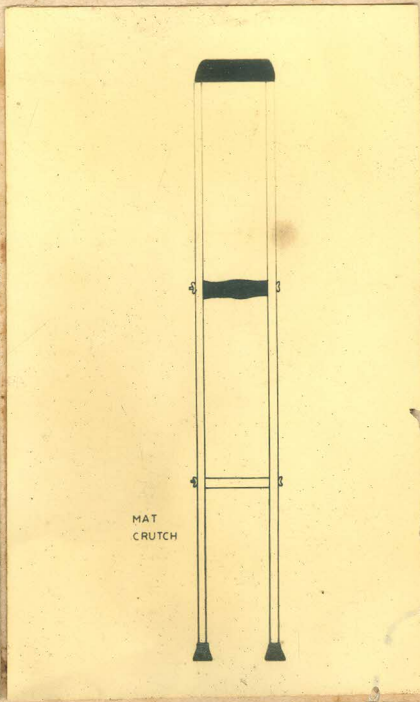
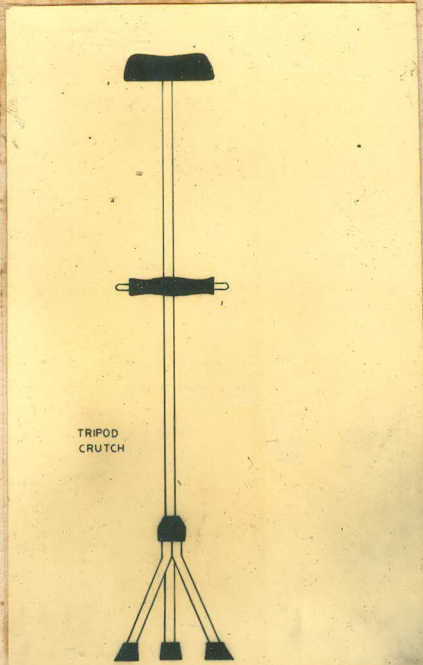
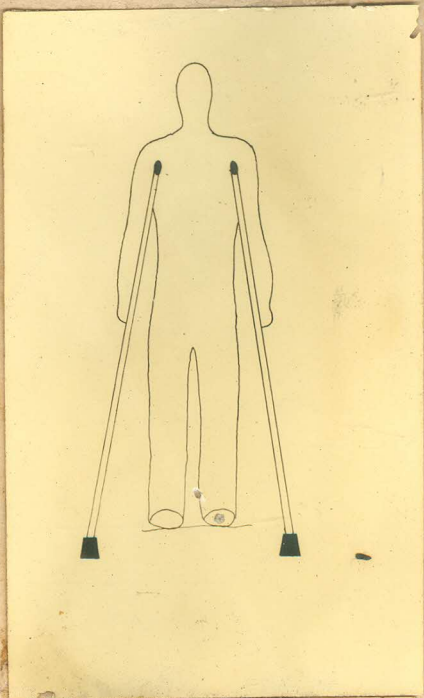
This is used by single leg lame person. A long (about 5 ft.) wooden stick or bamboo stick is held by both hands and is used such that it serves as one leg. The whole body is pivoted around this stick on every step of walking. This method is tedious to use. But many people in India use this because of its low investment.

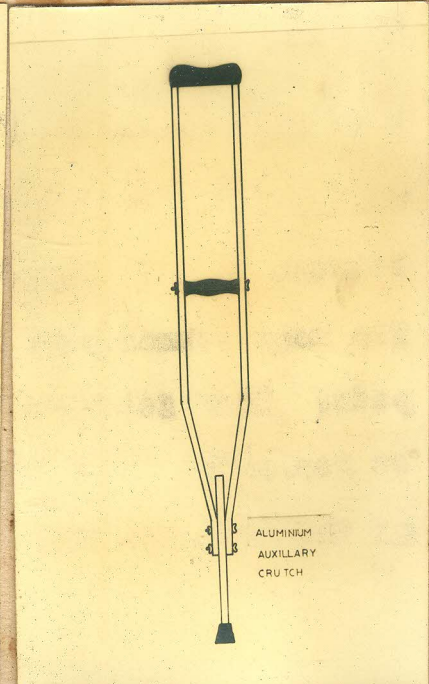
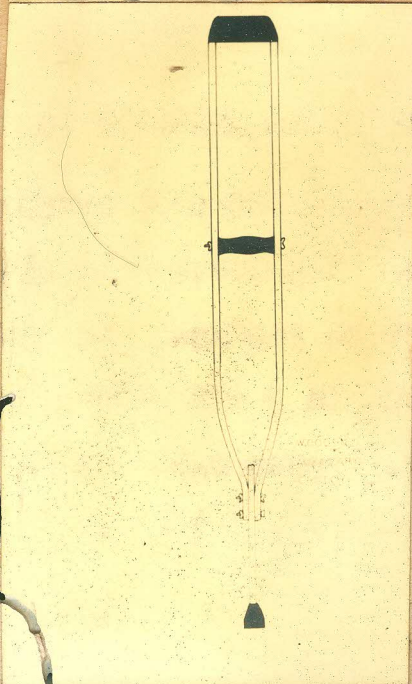
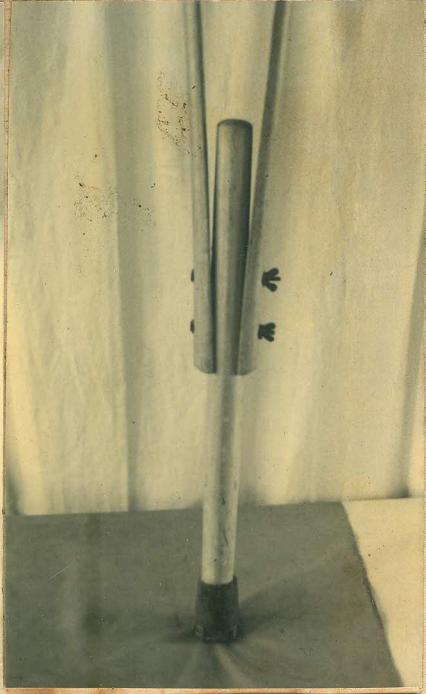
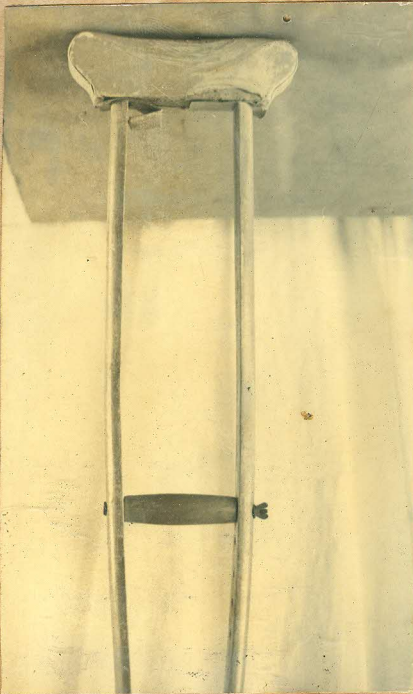
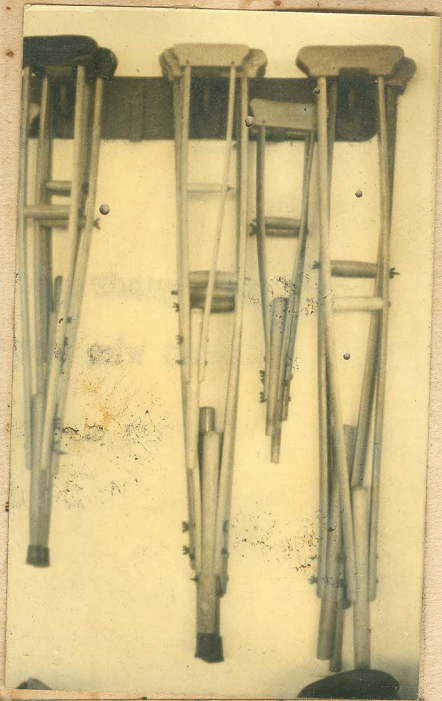
5.2 Auxillary crutches

Various types of auxillary crutches used are

- . adjustable double bar crutches
- . adjustable single bar crutches
- . mat crutches
- . tripod crutches
- . quadrapod crutches
- . double amputee crutches
- . elbow crutches

Adjustable double bar auxillary crutches are the most commonly used crutches. In India, wooden crutches are available. Other various types are required for specific cases.





Mat crutches are used by lame person for learning to walk.

Tripod and quadrapod crutches are used by very weak lame persons who would require more stability.

Elbow crutches are used by persons with very weak arms, such that it makes use of the upper arm.

Double amputees use double amputee crutches which are suitable to their low heights.

5.3 Forearm crutches

These are used by persons with strong arms. These are either adjustable or non adjustable.

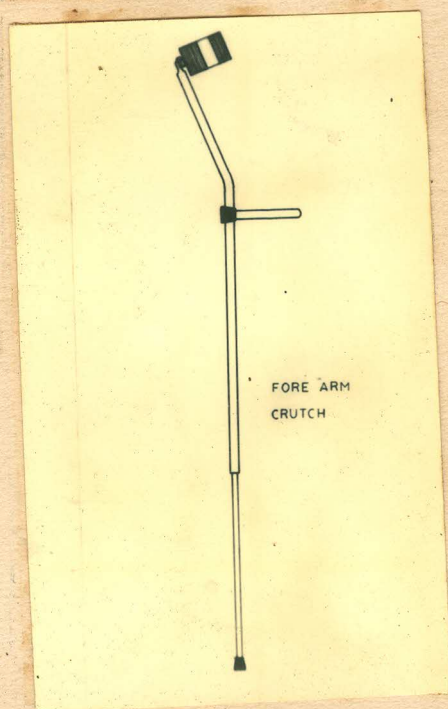
5.4 Crutch analysis

Adjustable wooden Auxillary Crutches:

These crutches support the shoulder thus supporting the weight of the body with the shoulder pads. The handle provided helps in controlling and moving the crutches, though part of the weight could be applied on the handle.

Different sizes are available suitable to all heights.

Wooden crutches are cheap. The cost range is between 30 - 50 rupees. Maintenance is also low. The most common part to be replaced are the rubber pads. They get worn out in 2 - 3 months and have to be replaced. They cost around 0.50 rupee. The life of the crutches vary from 2 - 3 years.



Sores in the armpits are regular occurrence among users in which period they are not able to use the crutches.

Since the auxillary nerve is pressed when the weight of the body is taken by the crutches, it might get affected and there is possibility of the upper limbs becoming paralysed.

Canadian Crutches (Forearm Crutches) :

These crutches take the weight on the handle through the palm and support the forearm. Different sizes are available suitable to all heights.

These crutches are very light and compact for use. They do not affect the auxillary nerve. The crutch requires the user to practice before he could use this.

The present cost range is between 150 - 200 rupees.

Information

Material for crutches

Wooden crutches

- Cedar wood
- Bamboo
- Balsa wood

Steel crutches

- Mild steel
- Chromium plated steel

Aluminium crutches

- Tubes

Common disabilities which limit their ability and willingness to travel.

- wait standing
- go more than one block
- go up stairs
- go down stairs
- go up/down inclines
- stoop, kneel, crouch
- lift and carry weights
- reach
- handle or grasp
- move in crowds
- travel long distance

6. PROBLEM ANALYSIS

The problems of the user vary depending on the type of lameness and the type of environment the lame person has to face.

6.1 Mobility

Walking :

A crutch user who is strong

- puts the crutches forward
- swings over the crutches to front
- again brings forward crutches

A crutch user who is weak

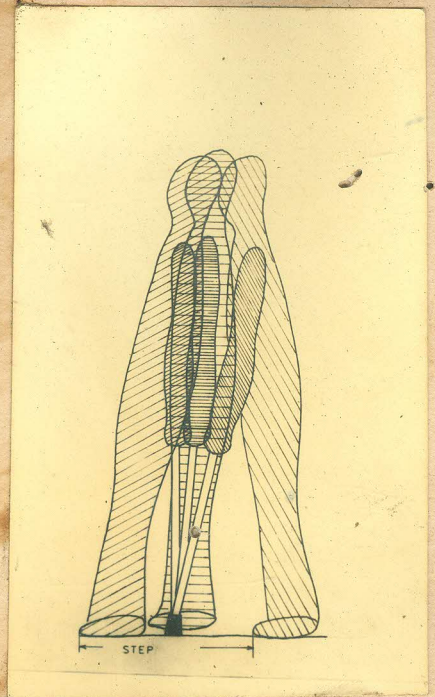
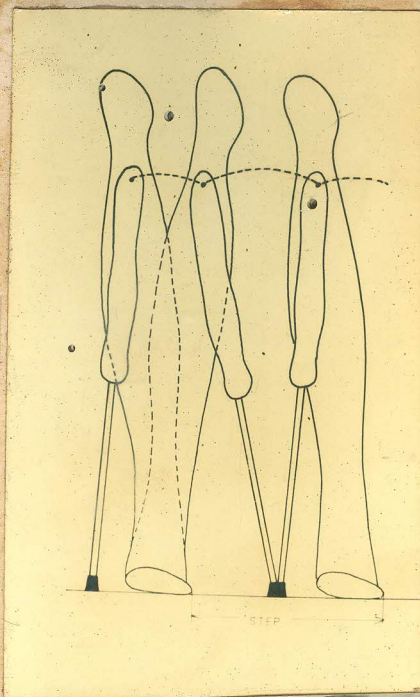
- puts the crutches forward
- moves his strong leg forward
- moves his weak leg forward
- again puts forward crutches

For every step of his travel he does two or three actions. This affects the speed of his travel.

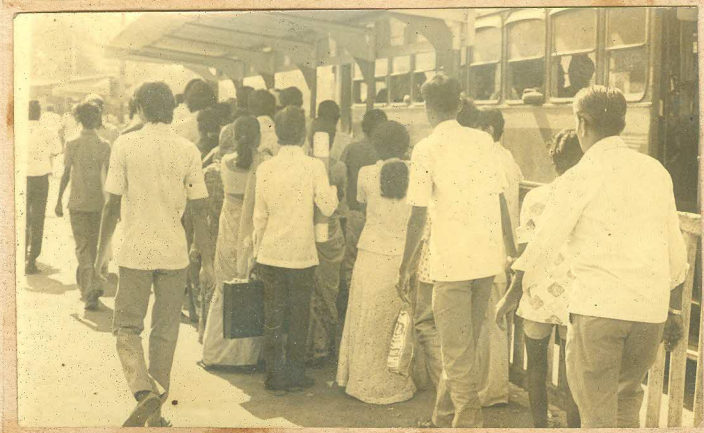
The crutches move in an arc when the swinging is done. This results in the user having an up and down motion for every step of his travel. This would be unnecessary strain on the user.

Walking speed :

In crutches the speed of travel can be increased by increasing swing or increasing the rate of swing



wait
standing



grasp

Information

Normal walking speed	4 - 5 km/hour
Cutches	3 - 5 km/hour
Wheel chair	2 - 4 km/hour
Tricycle	7 - 10 km/hour

or by increasing both at the same time.

The crutches being an external device, any effort to increase the speed of travel would tire the user easily. This invariably results in sores at contact points or resting areas i.e. armpits, forearm, palm.

Strong crutch users are found to walk faster than normal walking speed.

Walking distance :

Normal walking distance without resting is about 150 - 250 m for a strong crutch user and half that distance for a weak person.

The user requires to rest after this amount of travel. Auxillary crutch user does that by resting his weight on the shoulder pads. Resting is difficult for forearm crutch user.

Bus - Trains :

Boarding and travelling in buses and trains pose hurdles to the crutch users. Auxillary crutch users try to shift both the crutches to one arm and use the other arm for holding on to hangers etc. In Canadian crutches it is much easier since the hands can be free for holding on to something.

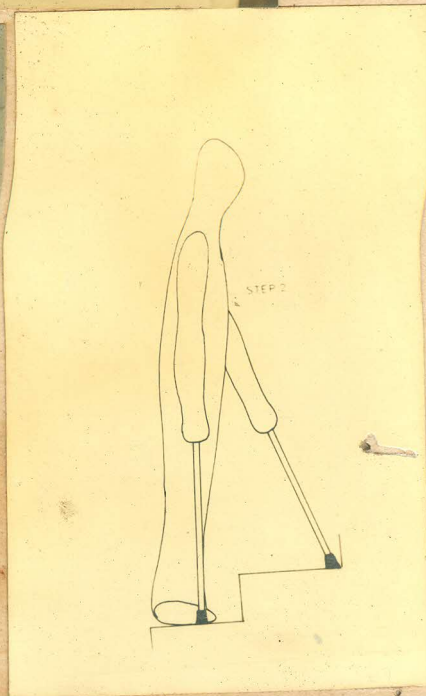
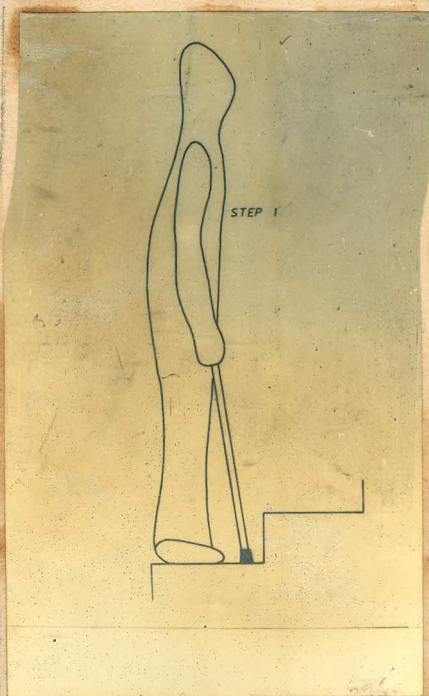
Climbing steps :

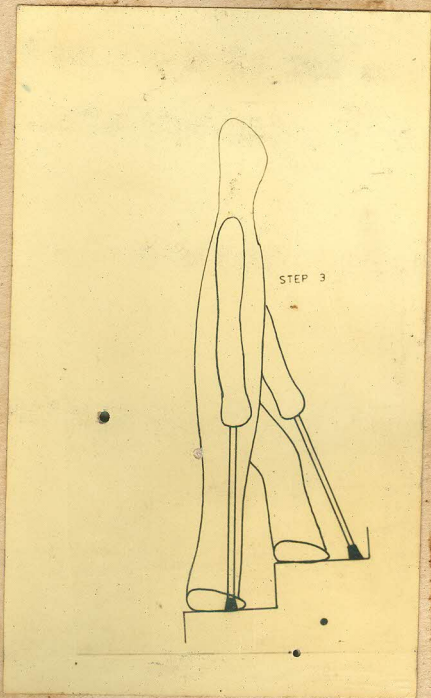
The stair case presents a big hazard for the lame



go up
stairs

2





go down
stairs



person. They usually make use of the side railings to pull themselves up while going up stairs. Otherwise the crutch user

- places the crutch (towards the weak leg) up
- places the strong leg up
- places the weak leg up by pushing against the crutch (towards the strong leg)
- Then brings up the crutch (towards the strong leg)

Though similar procedure is involved for forearm crutches, they are much more difficult to use while going up stairs, since they are less stable than auxillary crutches.

The user tires easily while going up stairs.

Coming down stairs:

Coming down stairs for the crutch users is much more easier than going up stairs. They

- place both the crutches down
- place the strong leg down
- place the weak leg down or
- place both the legs down at the same time.

Walking in crowd:

The crutch user requires more space for walking than a normal person because of the extra area needed to place the crutches on the ground.

The required space is about two times that of a normal person. Space is required on either sides, in front and at the back. Hence he has difficulty while moving in a crowd.

Carrying article:

The best way for the crutch user to carry weight is on the shoulder like a haversack. At present crutch users use swing bags hanging across shoulders. But they cannot carry much weight (1/2 to 1 kg.) since it would increase their effort to walk.

Safety features:

There are chances of the crutches slipping especially in rainy season and on very smooth surfaces. The user can lose his balance and fall down. If he falls down the crutch user has difficulty in getting up.

Sores:

Since constant contact and rubbing occurs at the contact areas, sores are regular occurrence among users. In this period it is difficult for them to use crutches.

Compactness :

The available auxiliary wooden crutches are bulky. In buses and trains it is troublesome to the co-passengers. Forearm aluminium adjustable crutches are compact compared to the auxiliary wooden crutches.

Weight of the crutch :

The available wooden and aluminium crutches weigh about each. This weight is considerable and has an effect to the performance of the user.

6.2 Investment and maintenance :

Wooden auxiliary crutches cost about 30 - 50 rupees.

Aluminium crutches cost about 150 - 200 rupees.

The rubber pads get worn out very fast and has to be replaced every 2 - 3 months. They cost about .50 - 1.50 rupees each.

Life span of the wooden crutches are about 2 - 3 years and that of the aluminium ones are 4 - 5 years.

Information

Upper limb muscles:

The limbs are moved to the thorax at only one small joint, the sternoclavicular. However, the shoulder girdle (clavicle and scapula) with its muscular attachment to the trunk securely anchors the arm to the body.

The brachial muscles rest on the shoulder pad. The shoulder pad should be in contact with maximum area of the muscles.

7. DESIGN SOLUTION

From the study of data it was felt that one common solution to solve all the problems at the same time would complicate the solution to the extent of becoming impractical. Also the needs of each individual user and the type of user varies a lot. Hence according to the different needs of the user, the following solutions have been conceptualised such that the user can use the one most suitable to him.

- versatile crutches
- redesign of forearm crutches
- increasing speed and comfort of walking
- staircase climbing attachment
- ideas for future crutches

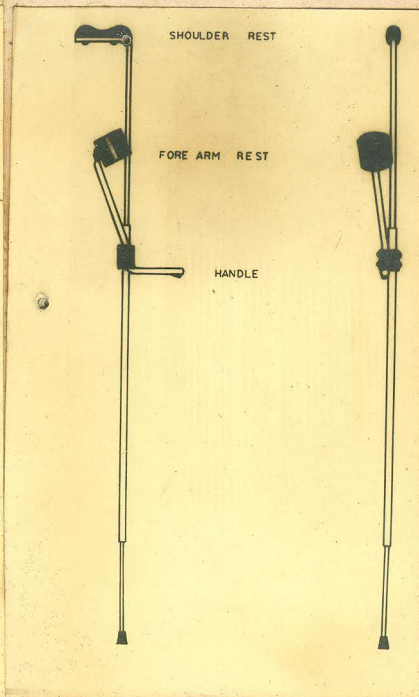
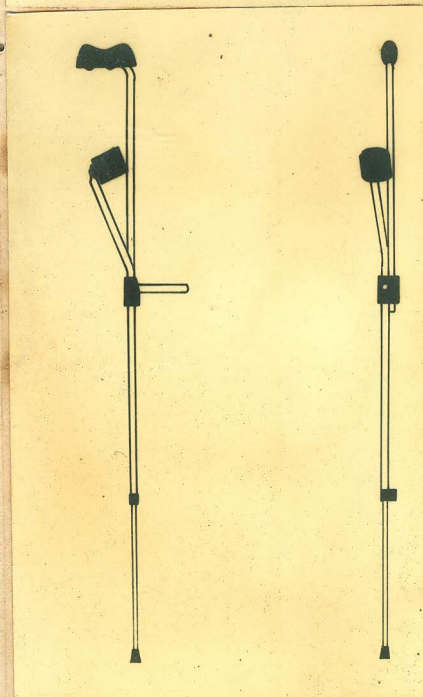
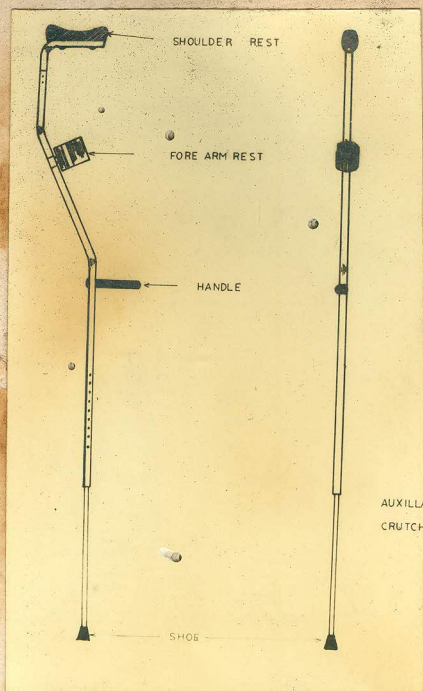
7.1 Solution - Versatile crutch :

This crutch is designed for the user to utilise his supporting points effectively.

It consists of a shoulder rest, forearm rest and a hand grip. The shoulder rest can be pushed down and only the forearm rest and hand grips can be used.

In this crutch the user has the choice of distributing his weight at various resting points depending on his comfort.

A strong armed crutch user can apply most of his weight on the handle and forearm rest and use the



The shoulder rest as a pivot point.

The user can push the shoulder rest down and use the crutch like forearm crutches.

For resting the user can make use of shoulder pads.

The pivoting of the forearm rest is useful when the user needs to grasp anything. The shoulder straps can also be used for the same purpose.

The crutches can be made compact by pushing the shoulder pads down and by using the telescopic arrangement.

For those who have weak arms the crutches can be made of a single tube, since they will not be able to use it as forearm crutches.

The crutches are made out of available material and designed for small-scale production.

7.2 Solution - Redesign of Forearm Crutches :

For those who have strong arms shoulder rests are not necessary and hence forearm crutches would be ideal.

Hence it was decided to design these crutches economically using available materials and for small-scale production.

The crutches are designed in three sizes suitable to all heights.

7.3 Attachment - increasing speed and comfort :

The crutches move in an arc while swinging for every step of the travel. This generates an up and down motion for the user which is uncomfortable and strains the shoulder resting points.

To avoid this the base of the crutch is made in an arc of a circle, the radius being the length of the crutch and the chord length being one step.

This would ensure that the height of the crutch remains constant. Hence strain on shoulder resting points are less.

The user now swings an extra distance equal to the length of the base. Hence the distance travelled in every step of his travel increases. The stability of the crutches is also more.

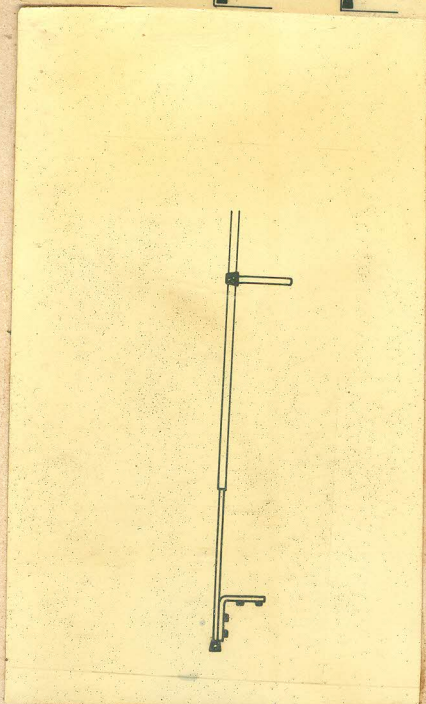
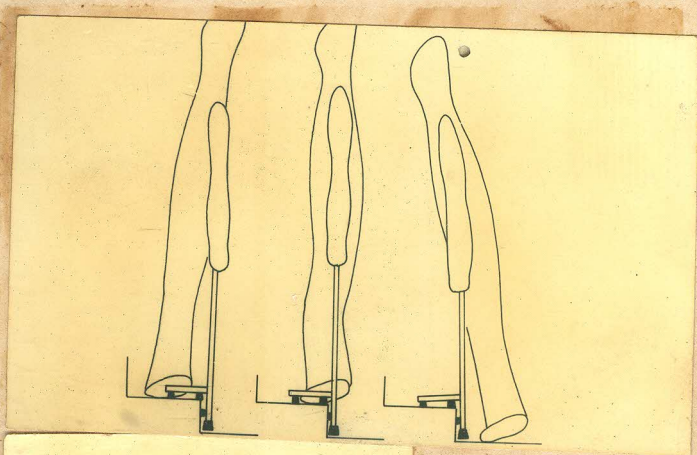
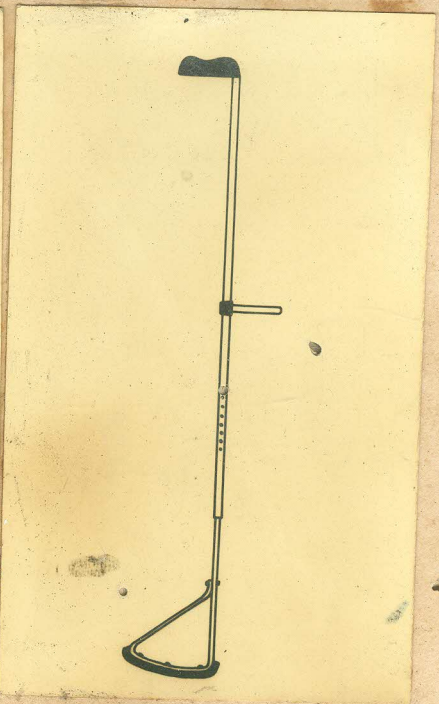
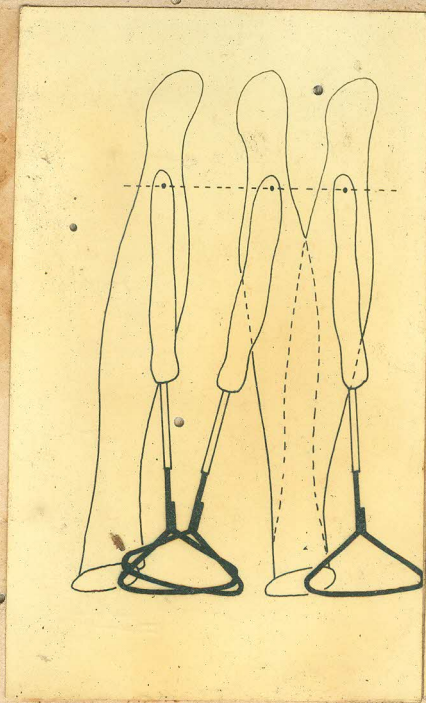
This crutch requires that the surface the user uses should be even. It is ideal for indoor use and if the ground is even it can be used outdoors.

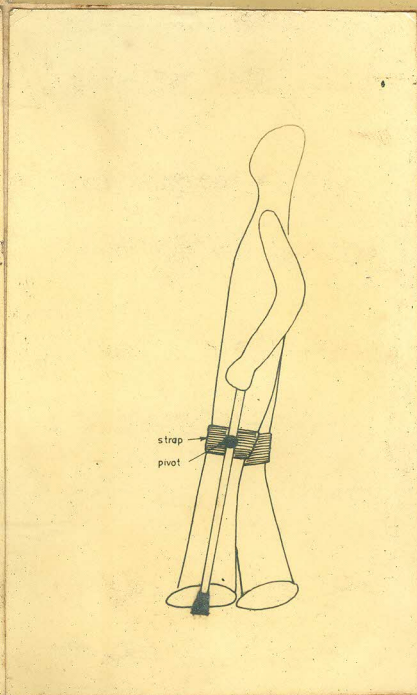
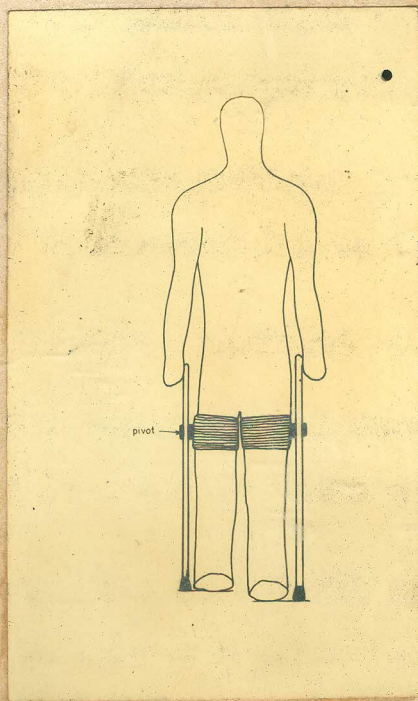
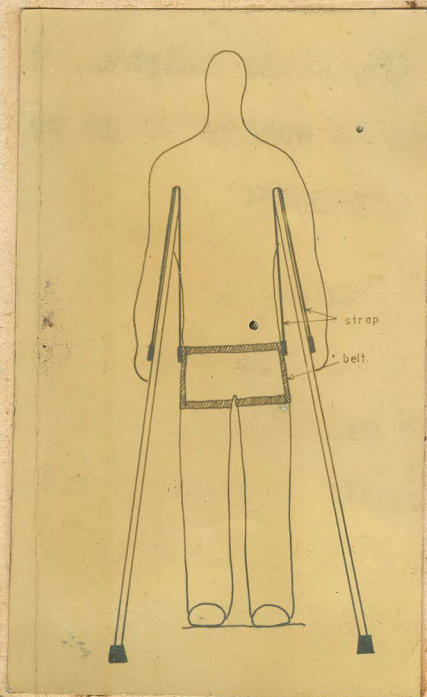
These crutches are suitable for patients in hospitals who are weak, by old people and by weak lame persons.

These crutches are suggested as an attachment to normal crutches.

7.4 Attachment - stair case climbing:

Three to four steps are involved in going up stairs.





One of the main problems for the crutch user is that, that he is not stable and has to lift his weight up by the stair height. To reduce the steps involved and make it easier to go up stairs the following solution is suggested.

It consist of an L shaped grip which would grip the stairs. The user places this on one step ahead of him gripping it while going up stairs. Then he pushes himself up against both the handles and places his legs on to the next step. The grip ensures balance to the user and raises the crutch height by 3 - 4 inches.

Also while coming down stairs the L shaped grips can be turned backward and use for gripping the steps.

This solution is suggested as an attachment since not all crutch users have to use a stair case.

7.5 Solution - new crutch ideas :

These crutches make use of alternate points of support for carrying the weight of the user.

The first idea has belts worn around the hips of the user and the weight of his body is taken up by the crutches by means of two cords which are fixed to the crutches. The total crutch height is less than that of the shoulder level.

The second idea has also belts worn around the hips but the crutches are pivoted to the belt at the hips.

Thus he moves the crutches forward using his hands but the load is taken through the pivot by the crutches from the hips.

The main advantage in both these cases would be that the hip region would be supporting the weight of the body. Hence it would be more comfortable and less straining to the user.

8. DETAILS

8.1 Material

The various materials which could be used for construction of crutches are wood, aluminium and steel. Wood has short life and less strength. Steel is very heavy. Aluminium is light and has high strength to weight ratio. Hence Aluminium was chosen as the material to be used. Tube sections (circular) were used in construction of the crutches.

8.2 Ergonomical

The crutches are designed to suit all heights and variations in the body dimensions of the disabled people. For this they are divided into three groups of 3 - 4 ft., 4 - 5 ft. and 5 - 6 ft. and three sizes of crutches are constructed. The crutches have telescopic arrangement to suit variations in their body dimensions (arm length and shoulder to foot height).

The areas of support are increased in the versatile crutch design such that more muscles are used to support the weight of the body. The shoulder rest, forearm rest and the hand grip are designed such that there is maximum contact with the muscles.

8.3 Balance point

The line of application of the weight of the body is

so choosen that when the user applies weight on the crutches there is a moment forward. This helps the user in moving forward with less effort. Thus when he applies weight on the handle, the application of load gives him a forward moment which helps the user in moving or swinging forward.

8.4 strength

These crutches act as columns, the force acting along the axis of the tube. Using Eulers Buckling load equation, the tubes were choosen such that they can support three times the normal load.

8.5 Part details

Tube selection and bending :

The tubes for 3 different height variations in users were choosen on the strength calculations. An inner tube concentric with the outer tube with minimum clearance was necessary for telescopic arrangement. From the available tubes in the market, tube combinations were choosen as shown in the table.

The basic tube is bent as shown in the height analysis for 3 different height levels of users. To this the shoulder pad, forearm rest, handle and telescopic extensions are fixed.

Shoulder pad :

The shoulder pad is fastened on the aluminium tube

bent at right angles at the top of the crutch. It consists of a wooden piece fastened to the aluminium tube which is padded with foam rubber. This is covered by rexin and a removable cloth covering. A shoulder strap made of spring steel and enamel painted is fixed to the aluminium tube.

Forearm rest :

The forearm rest is made of heat formed P.V.C. sheet. This is fixed to the aluminium tube. In case of forearm crutches it is fixed to the hinge which in turn is fixed to the pressed aluminium tube.

Handle :

Handle is made of turned aluminium or wooden piece covered with rubberised plastic handgrip. The handle is fixed to the tube by means of a screw or a cast aluminium piece.

Telescopic extension :

It consists of two concentric tubes with minimum clearance, the inner one sliding inside the outer tube. For fixing at different levels a M.S. pin with spring backing is provided in the inner tube. This locks into different holes in the outer tube.

Shoes :

The available rubber pads are made use of. These are fixed to the aluminium tube at the bottom by means of an aluminium or P.V.C. sleeve.

Stair case climbing attachment :

It consists of an aluminium rod hinged near the bottom such that it can become perpendicular to the crutch. This is fixed to an offset spring. Rubber pads are provided on the aluminium rod.

Increasing speed and comfort attachment :

It has an aluminium rod bent in an arc equal to the average length of the crutch. Rubber padding is provided on the bottom surface.

Aluminium tubes :

The following aluminium tube combinations are prescribed for manufacture of crutches.

. Outer diameter	19.05 mm,	Inner diameter	15.05 mm
	15.00 mm,		11.00 mm
. Outer diameter	19.20 mm,	Inner diameter	15.95 mm
	15.90 mm,		12.00 mm
. Outer diameter	12.70 mm,	Inner diameter	9.50 mm
	9.44 mm,		5.46 mm

8.6 Costing:

The cost of various crutches and attachments are shown in terms of the total material cost and approximate labour charges to manufacture them.

. Versatile crutches (pair)

Cost of material	- Rs.47.00
Cost of labour	- Rs.20.00

. Forearm crutches

Cost of material	- Rs.36.00
Cost of labour	- Rs.15.00

. Staircase climbing attachment

Total cost	- Rs.24.00
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. Comfort and speed increasing attachment

Total cost	- Rs.12.00
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DRAWINGS

AUXILIARY

CRUTCH

SHOULDER REST

FORE ARM REST

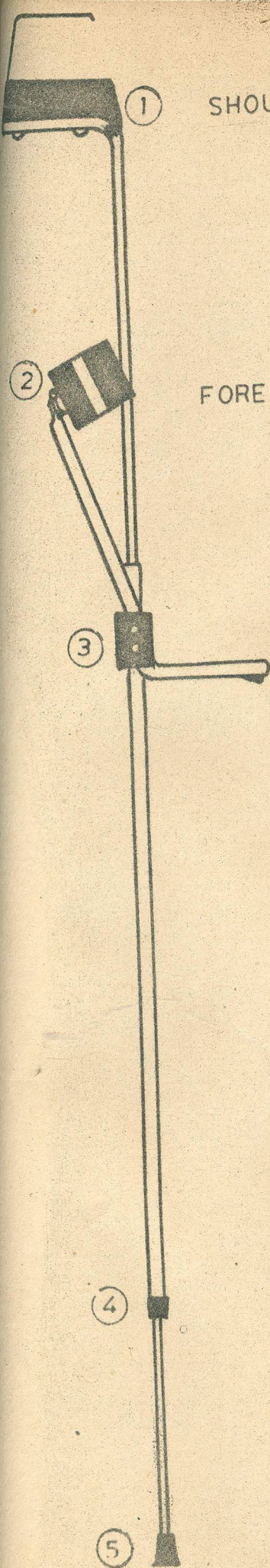
HANDLE

AUXILLARY
CRUTCH

for details

refer  drg

SHOE



①

SHOULDER REST

②

FORE ARM REST

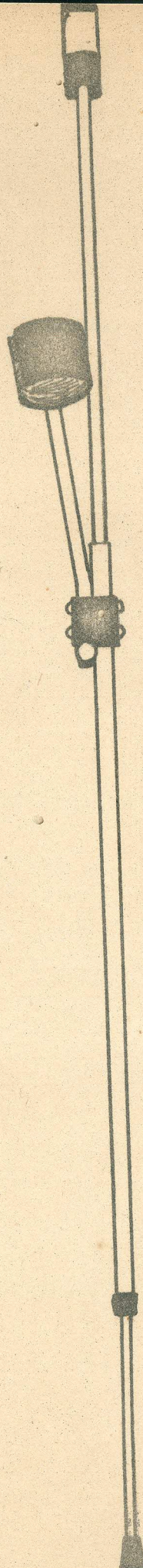
③

HANDLE

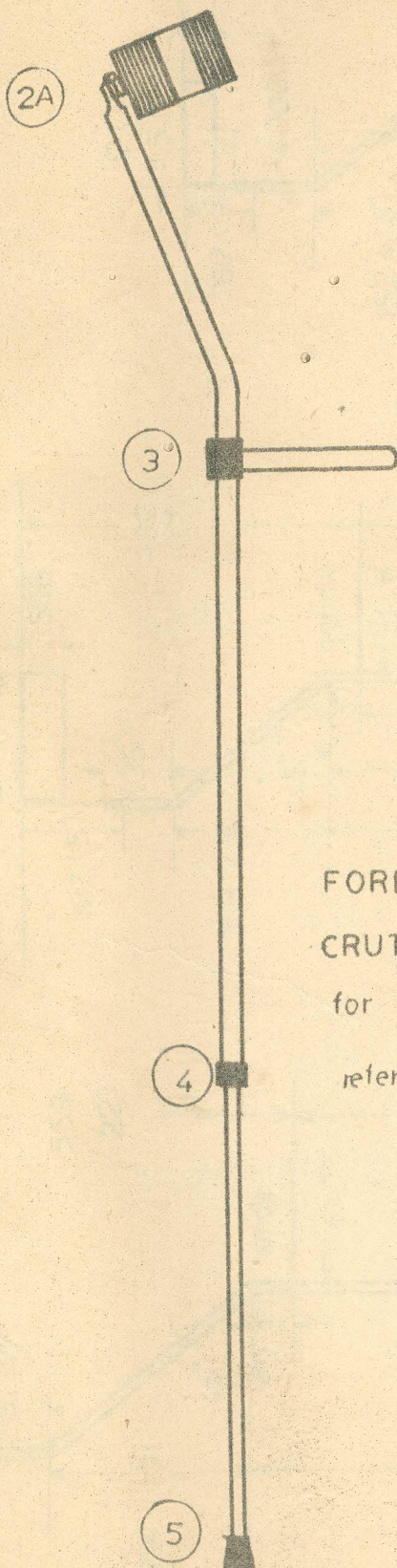
④

⑤

SHOE

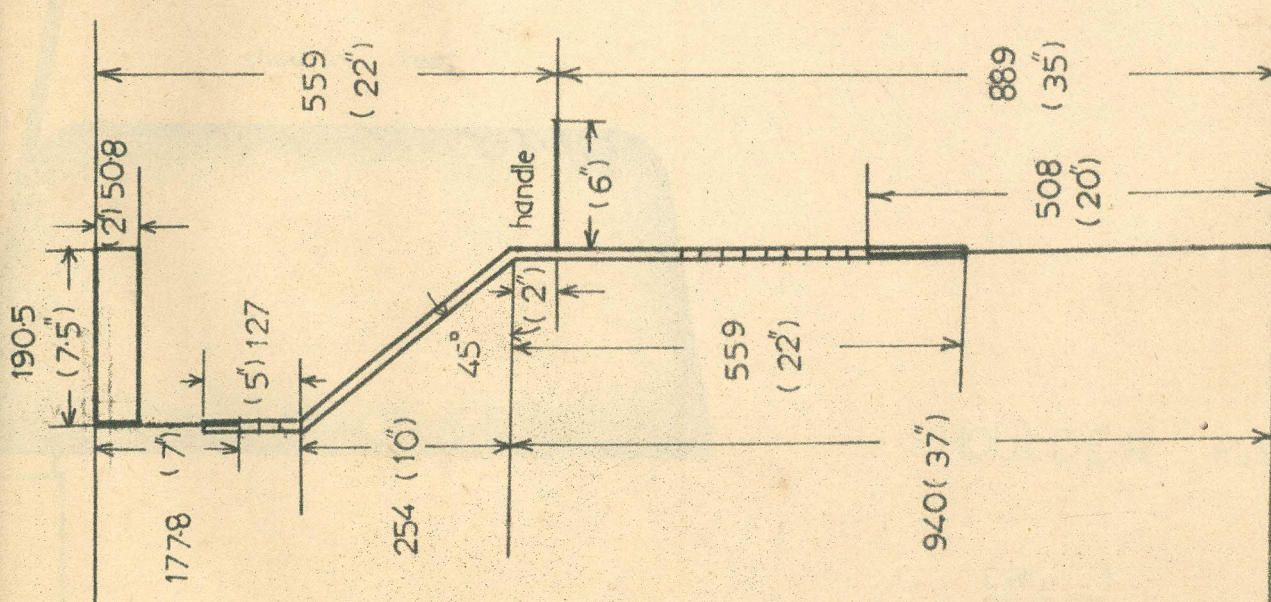


VERSATILE CRUTCH



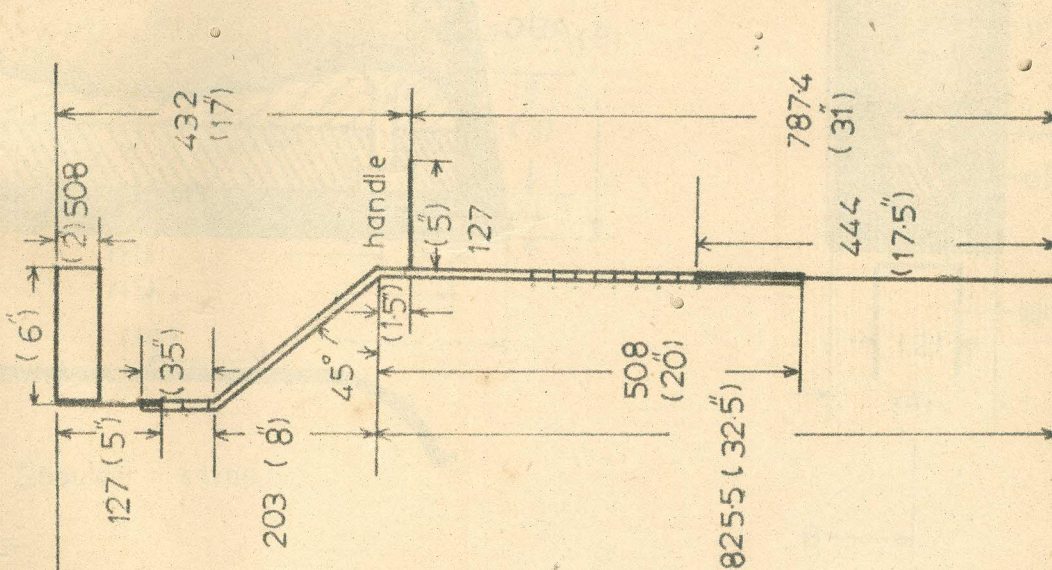
FORE ARM
CRUTCH
for detail

refer  drg

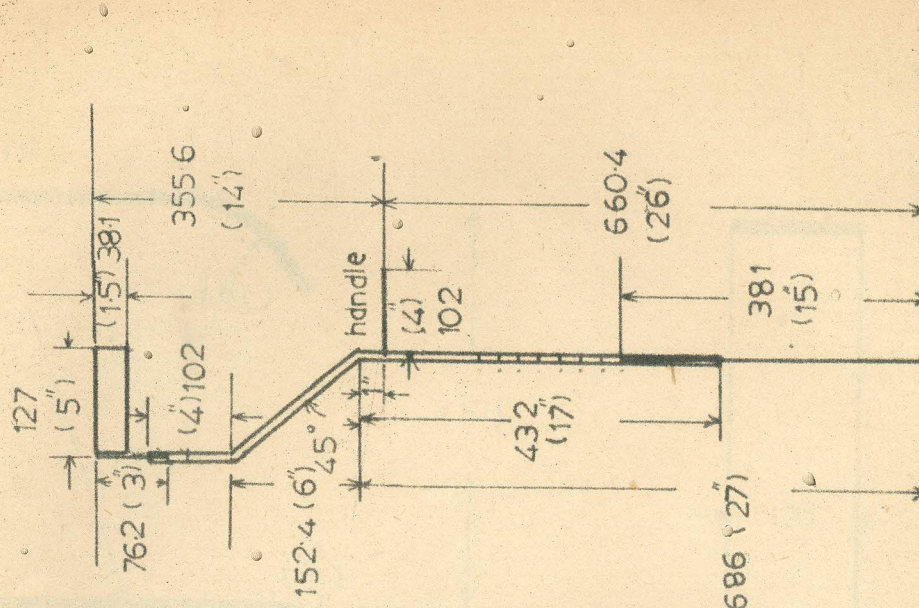


height - 72" - 60"

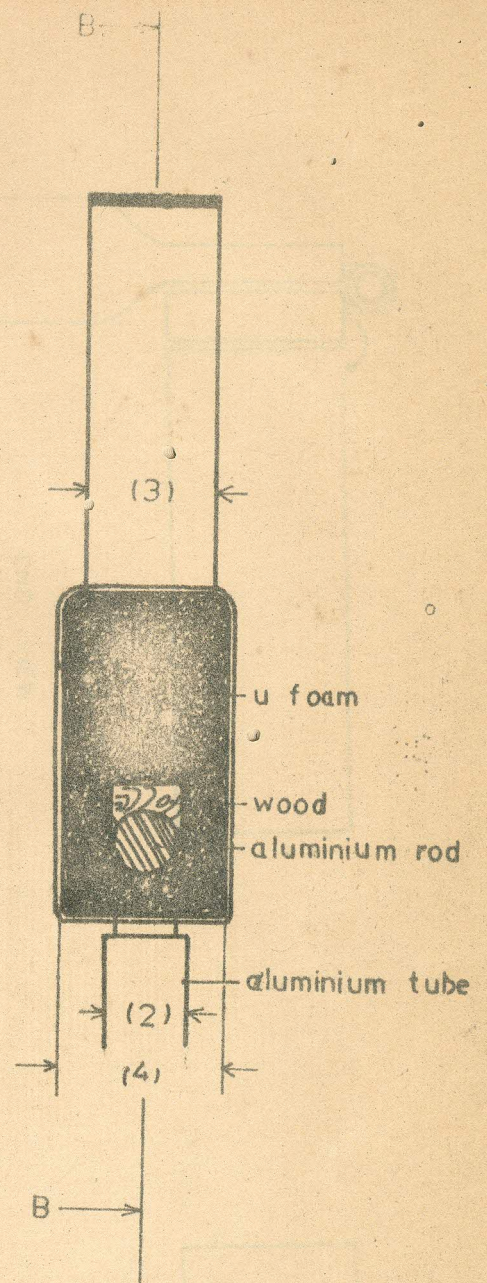
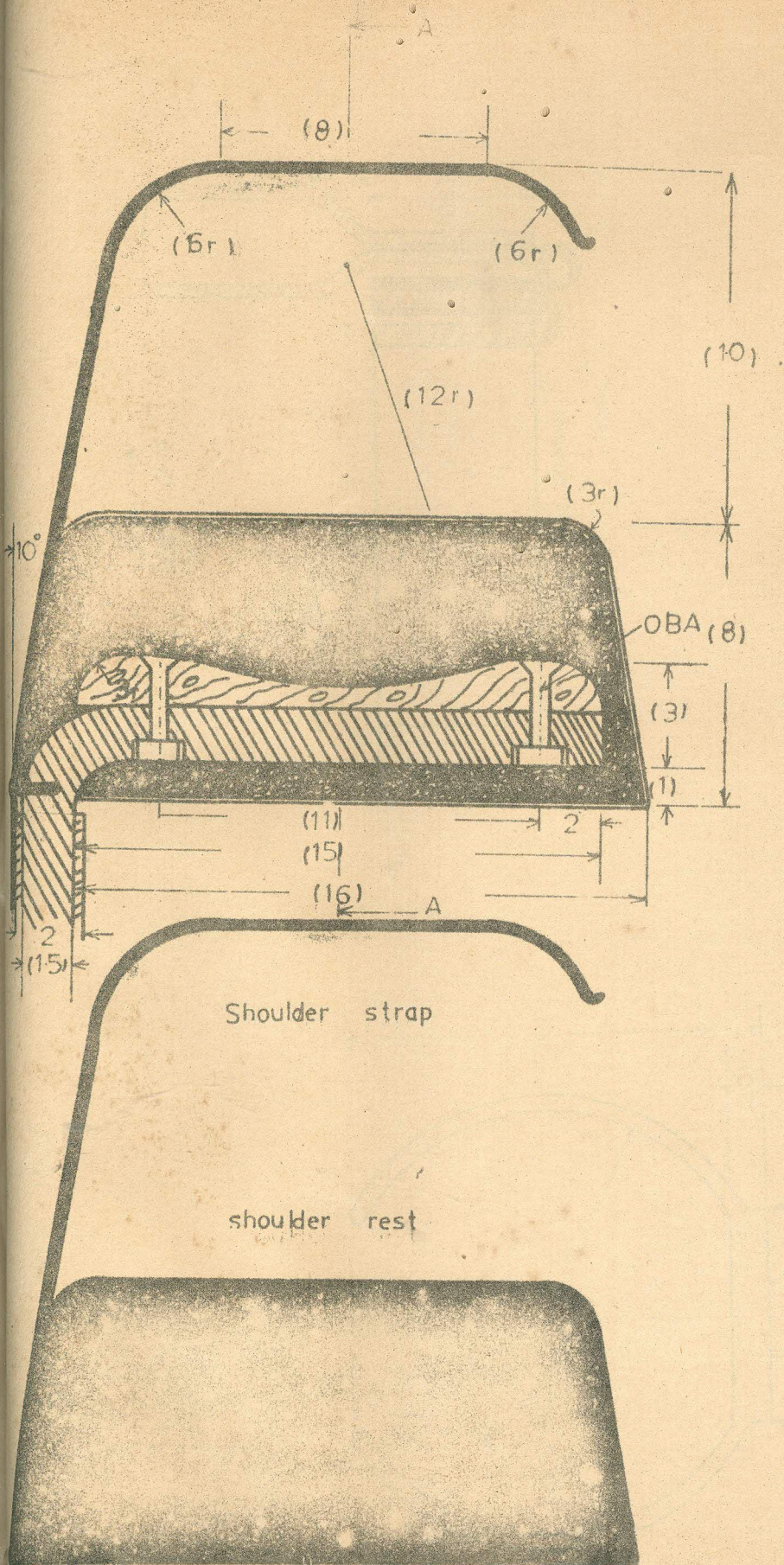
HEIGHT ANALYSIS CRUTCH DIMENSIONS



height - 60" - 48"



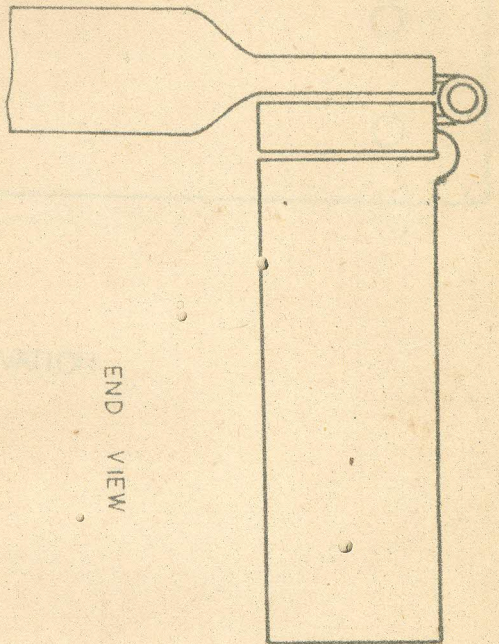
height - 48" - 36"



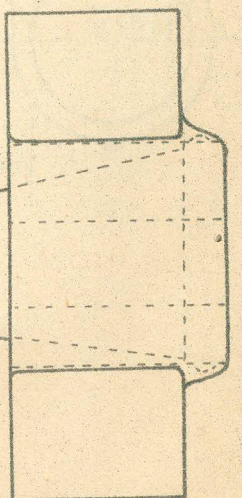
SHOULDER PAD

DRG. 1

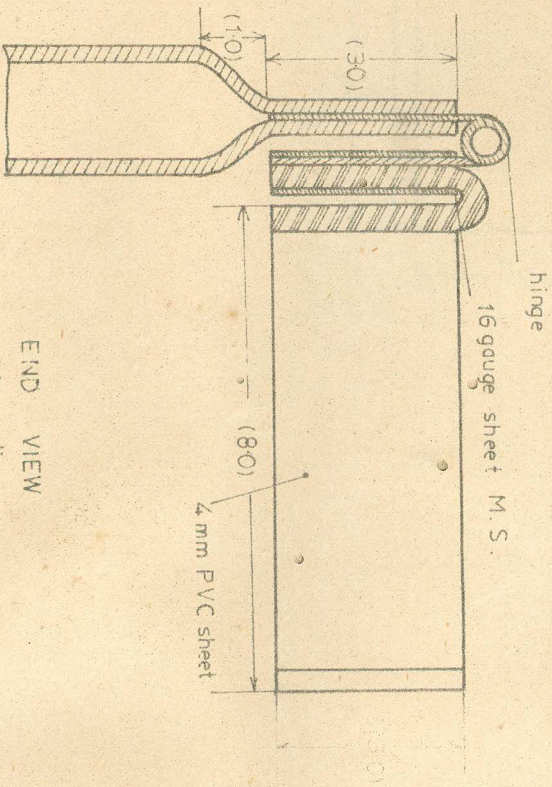
FULL ELEVATION



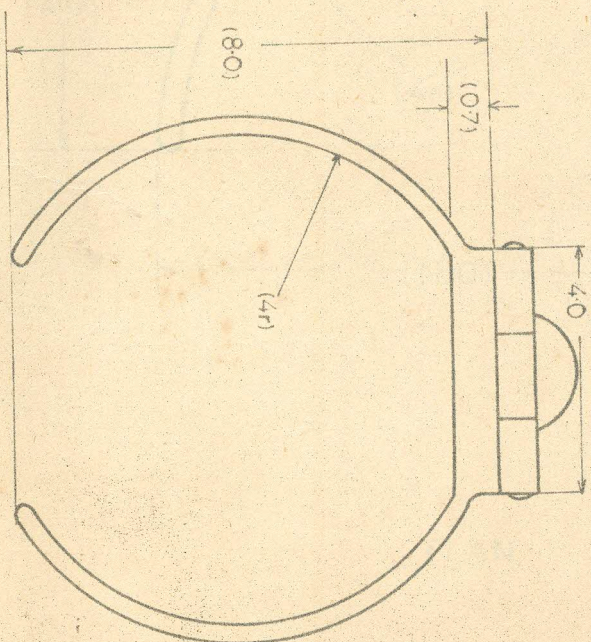
END VIEW



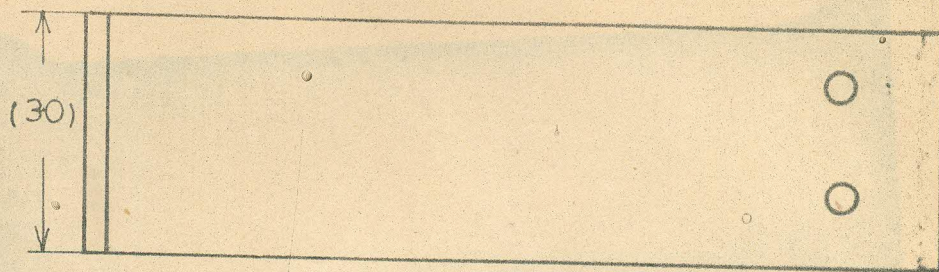
ELEVATION



END VIEW
mid section

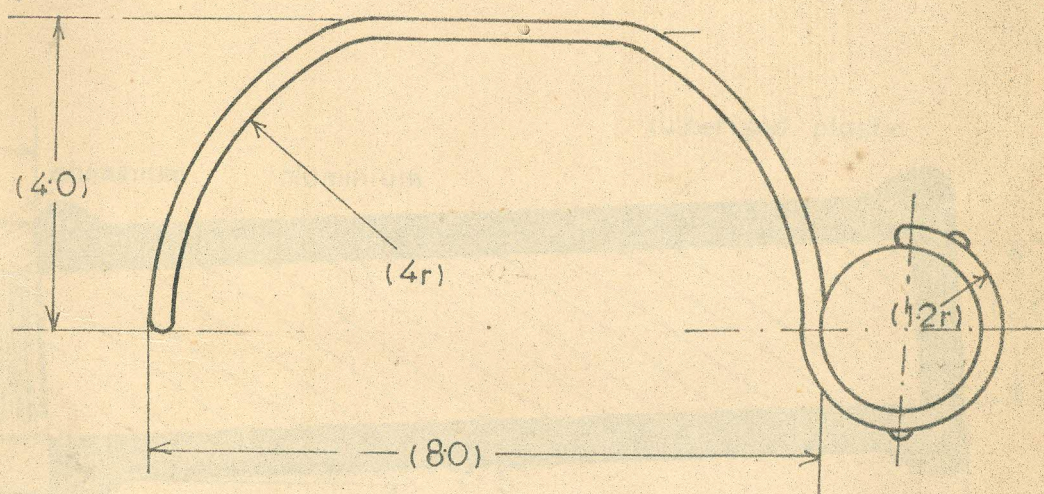


PLAN



ELEVATION

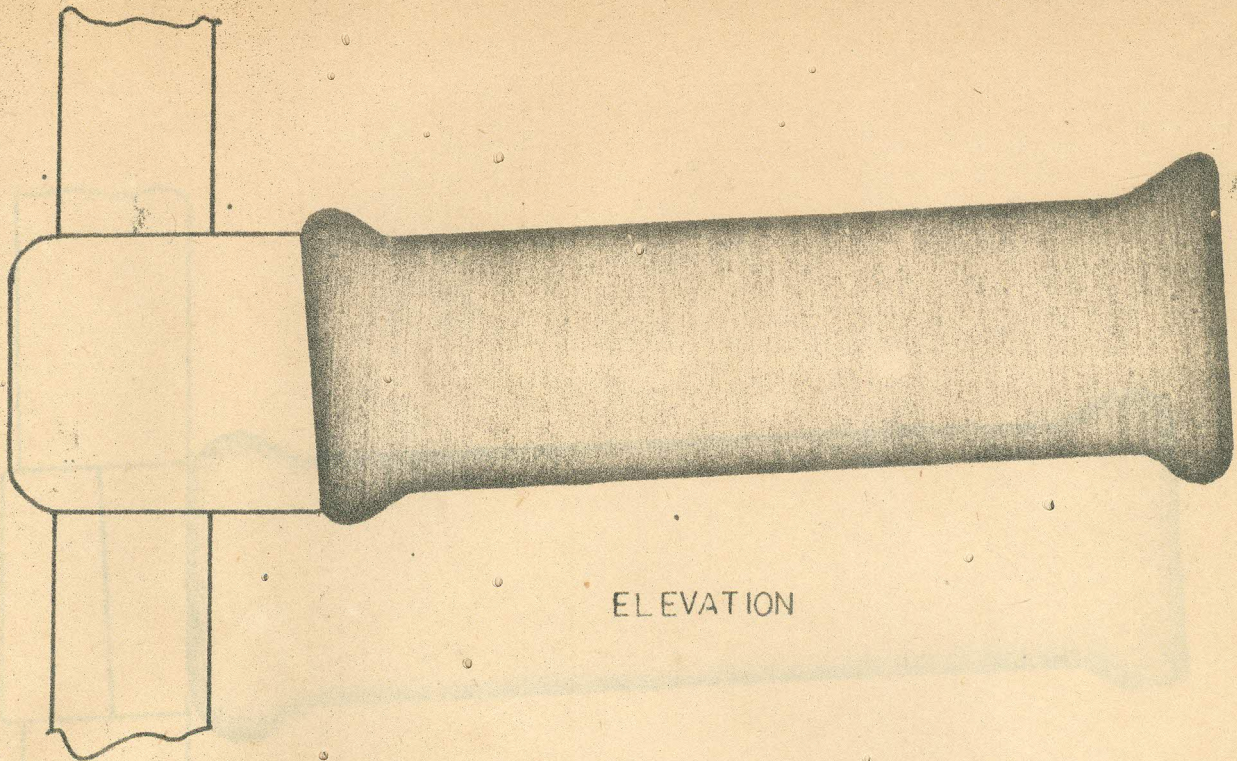
gauge M.S. sheet



PLAN

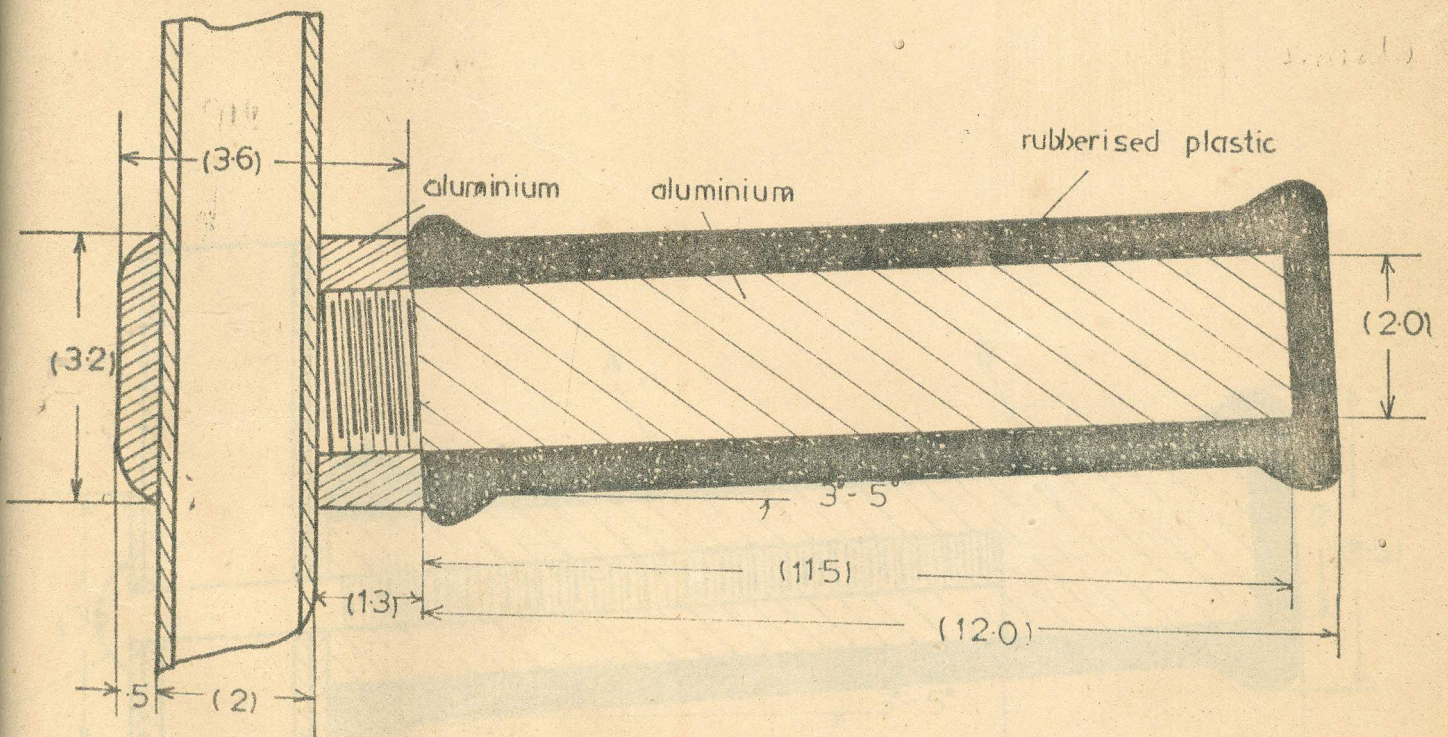
FORE ARM REST

DRG 2B



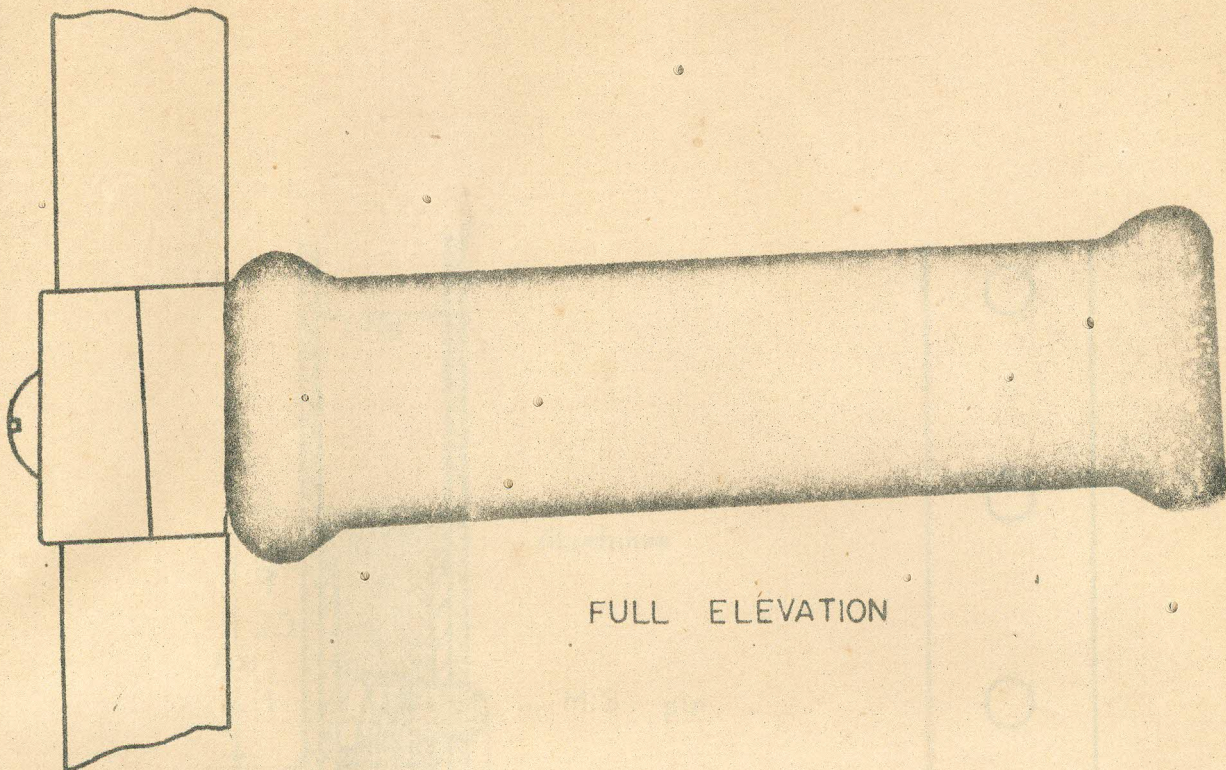
ELEVATION

FULL ELEVATION

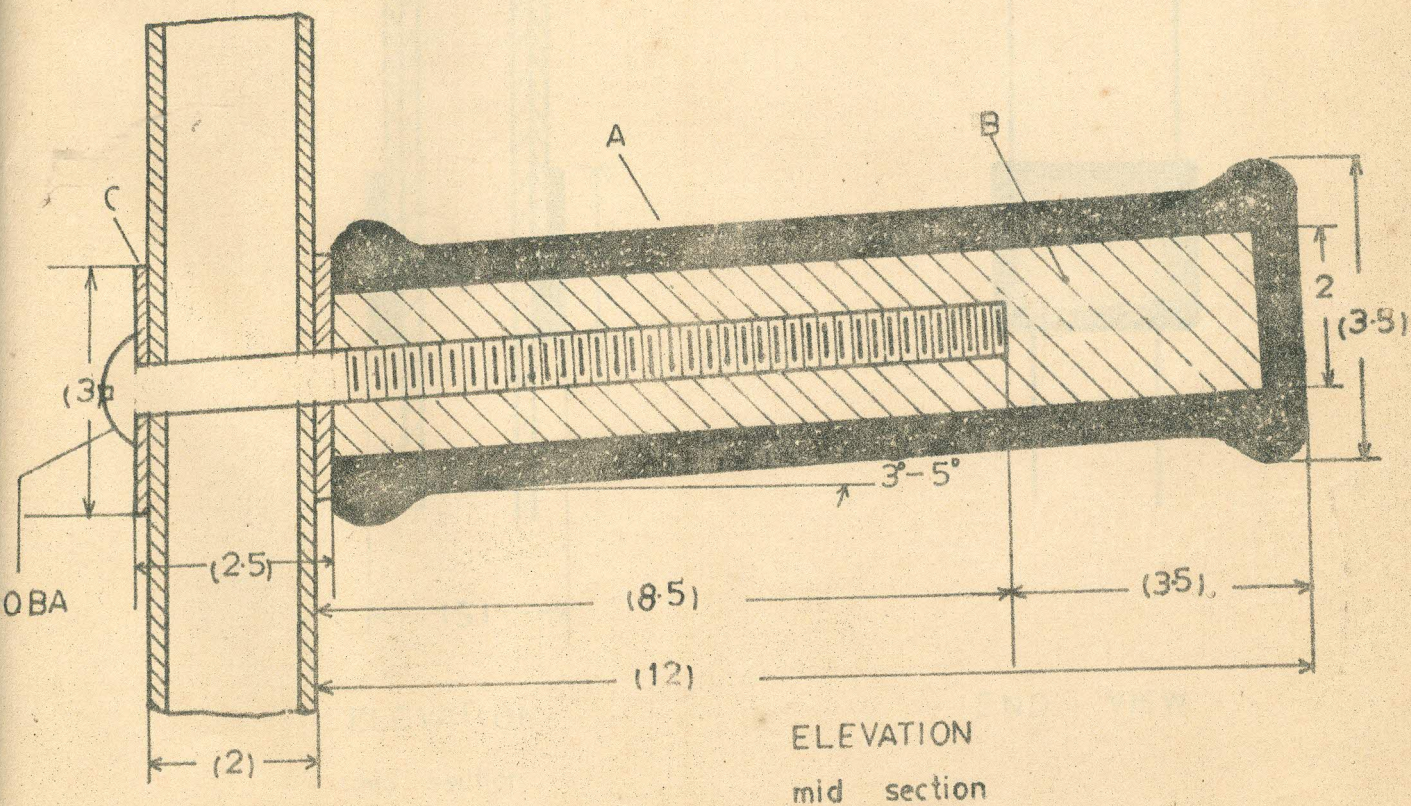


ELEVATION

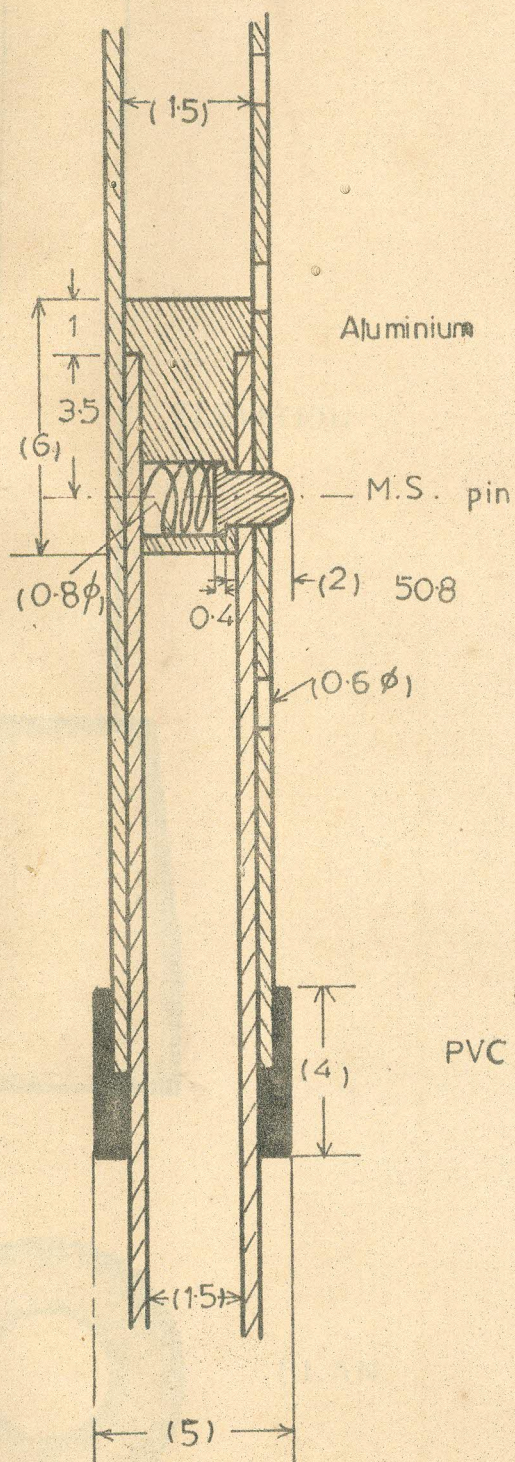
mid section



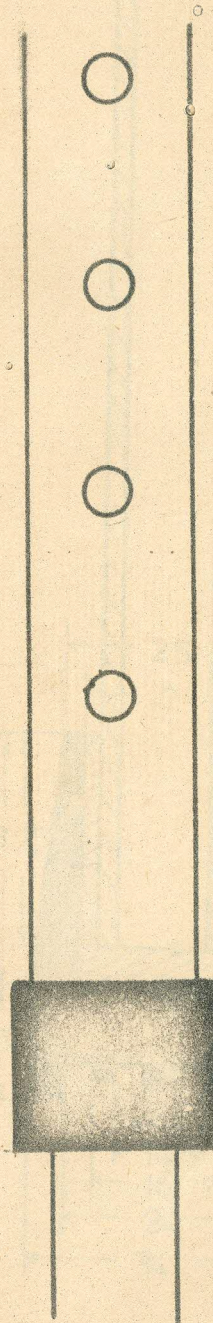
FULL ELEVATION



ELEVATION
mid section



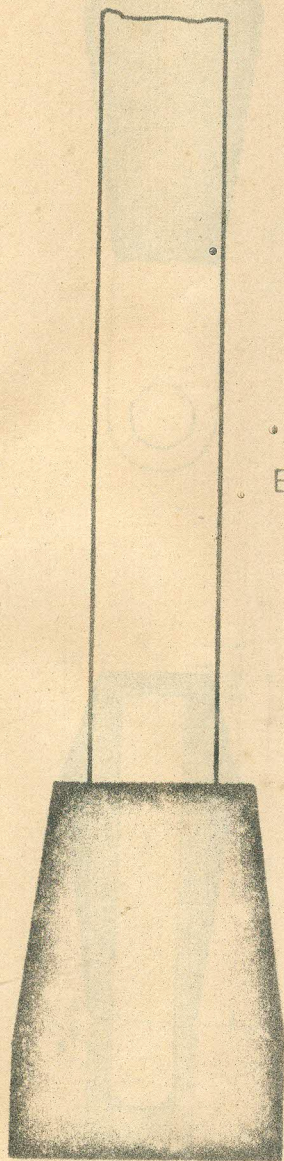
ELEVATION
mid section



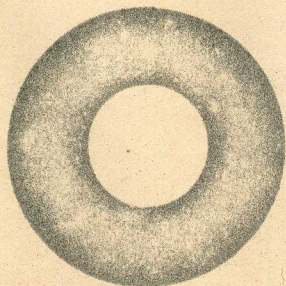
END VIEW

TELESCOPIC

arrangement



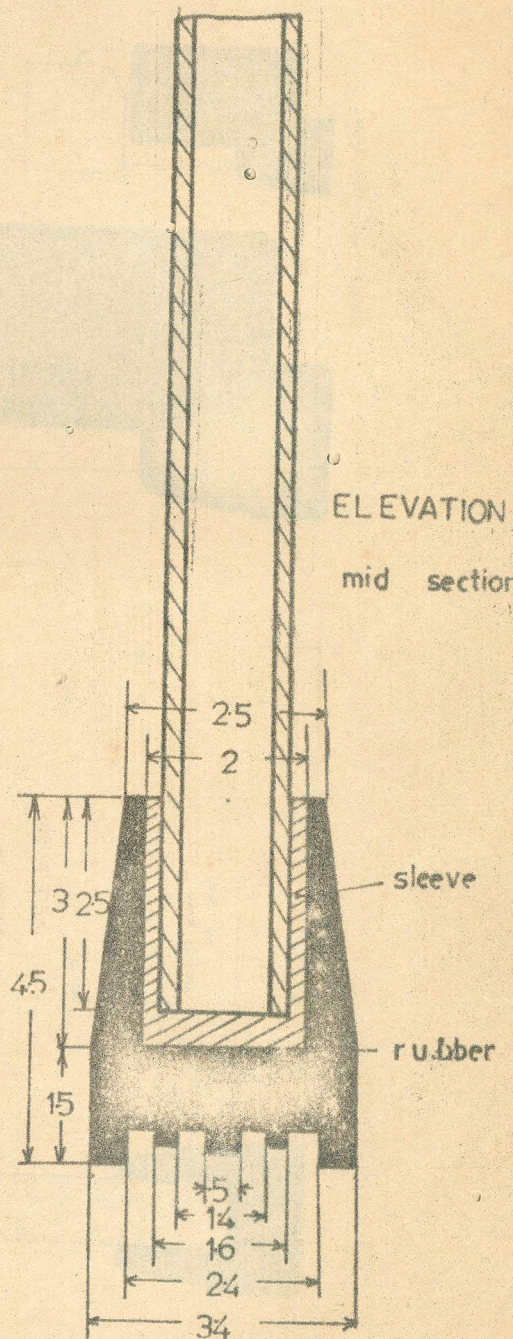
ELEVATION



PLAN

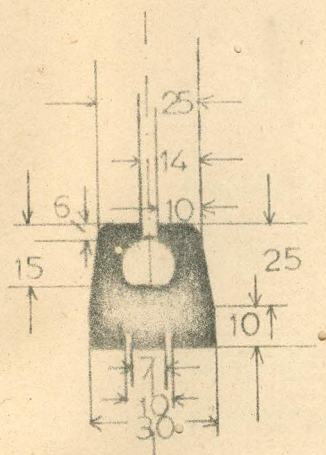
SHOES

DRG. 5

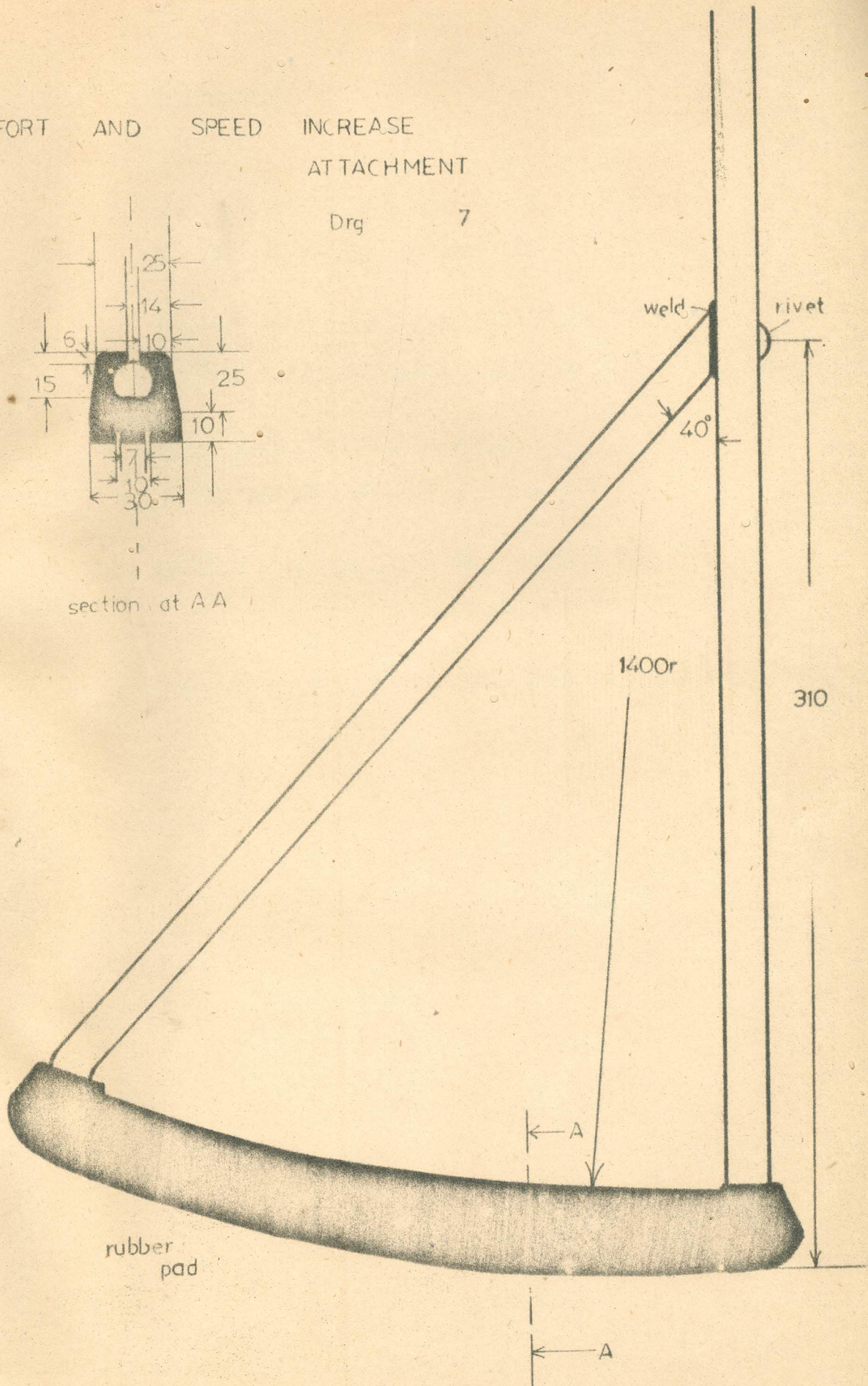


COMFORT AND SPEED INCREASE ATTACHMENT

Drg 7



section at AA



REFERENCE

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