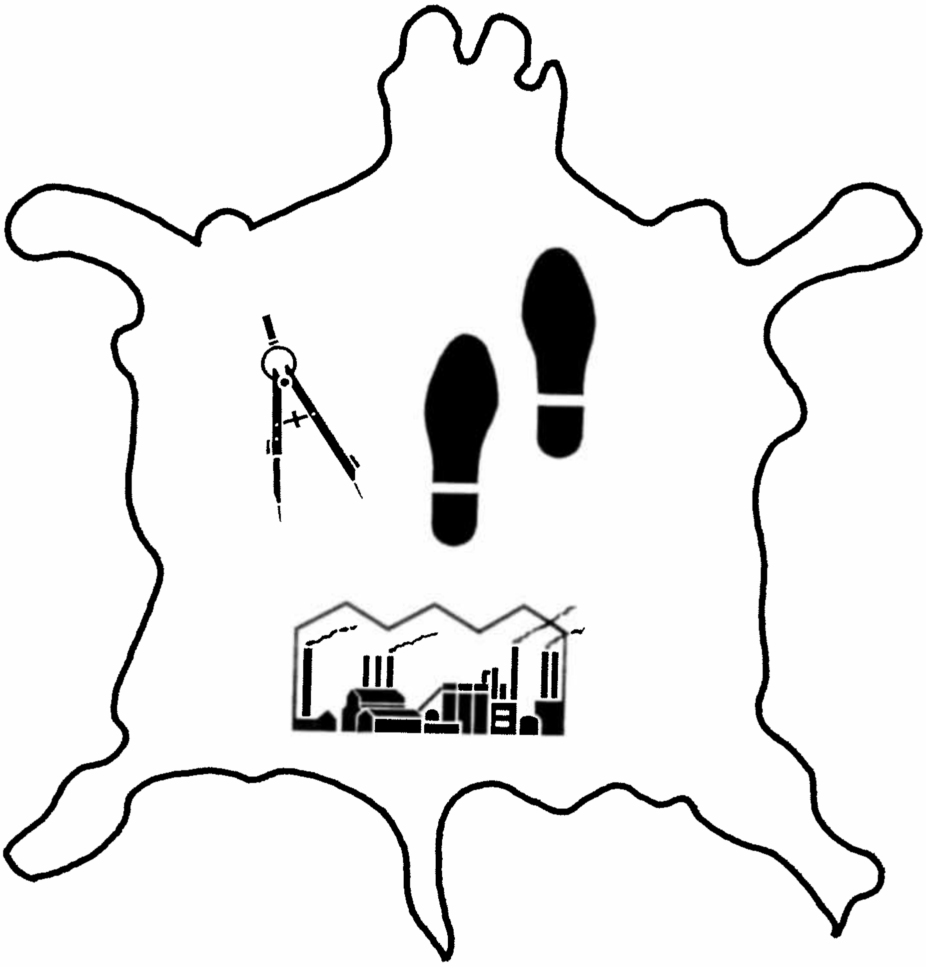
SHOE INDUSTRY

DIPLOMA COURSE

MATERIAL AND RELATED SCIENCE*



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This learning element was developed by the UNIDO Leather Unit's staff, its experts and the consultants of the Clothing and Footwear Institute (UK) for the project US/PHI/85/109 and is a part of a complete Footwear Industry Certificate/Diploma Course. The material is made available to other UNIDO projects and may be used by UNIDO experts as training aid and given, fully or partly, as hand-out for students and trainees.

The complete Certificate/Diploma Course includes the following learning elements:

Certificate course

-Feet and last
-Basic design
-Pattern cutting
-Upper clicking
-Closing
-Making
-Textiles and synthetic materials
-Elastomers and plastomers
-Purchasing and storing
-Quality determination and control
-Elements of physics
-General management
-Production management
-Industrial Law
-Industrial accountancy
-Electricity and applied mechanics
-Economics
-SI metric system of measurement
-Marketing
-Mathematics
-Elements of chemistry

Certificate/Diploma course

-Closing
-Collection building
-Advanced technology
-Work study
-The role of the production manager
-Production planning
-Material purchasing & control
-Quality control
-Material and related science
-Adhesives
-Pattern making and engineering
-Shoe costing
-Grading

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FIBREBOARDS

Some footwear components are produced by bonding together fibrous materials into sheets. These materials are known as fibreboards and used mainly for insoles but also for stiffeners, counters, toepuffs, reinforcing, patterns, templates, etc.

Fibreboards are made from vegetable materials (wood pulp, cellulose, waste paper, carton) or from animal fibres (leather scrap)

1. Cellulose board

Cellulose is found in the cell walls of plants, it is a carbohydrate used as raw material for a number of products, namely for paper (fig. 1). Depending from the origin, there are different grades of cellulose and depending from the manufacturing process there are different types and qualities of cellulose based materials.

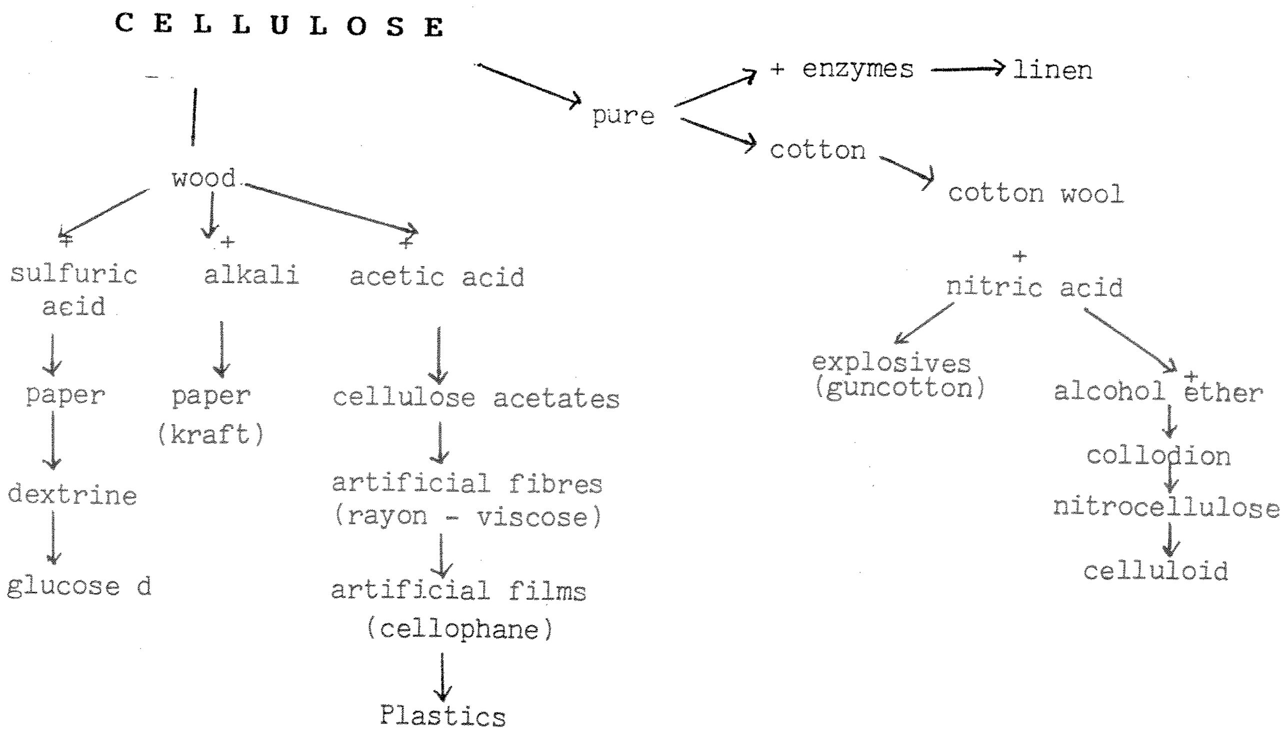


Fig. 1

Paper is generally made from wood pulp, but in the manufacture of paper board other cellulose fibres (sisal, hemp, waterlilie) and also scrap of waste of ropes, sacks, textile fibers, waste paper and carton can be mixed with the wood pulp.

There are two main types of cellulose boards; the soft type used for insole and the hard type used for seatboards, shanks or reinforcement. The latter has a lower binder content and is very rigid. Depending on the quality of the fibres and method of manufacture, there are different grades of hard board and in many countries those grades are identified by a standardized color:

Grade I	colored red
Grade II	colored blue
Grade III	colored grey

2. Animal fibre boards

These are usually made from leather scrap comming from the tanneries or footwear factories. Because of its hydrophilic character, waste of vegetable tanned leather is preferred to chrome tanned scrap. Leather board should have at least a 75% leather fibre content.

3. Mixed leather/cellulose boards

These boards are manufactured from a mixture of leather and cellulose fibres. Content of leather fibres varies from 10 to 50%.

4. Synthetic fibres boards

These boards consist mainly of polyester, polyamid, polypropylene, acrylic, cellulose acetates fibres, either alone or in blends.

5. Binders

To bond the fibers together, binders are used such as rubber latex, acrylic resins, starch, polychloroprenes.

Other constituents are added to the compound to increase the water resistance (rosine), to soften the material (oils, plasticizers), to give color (dyes, pigments) or to increase the weight and substance (fillers)

6. Manufacture of fibreboard

6.1 Beating

The fibrous material is first chopped and ground and then pulped and beaten with water into a thick mash or slurry. Binders, stabilizers, coloring matter, coagulants and fillers are added during the beating.

The beating stage is important because it affects the fibre properties. In general, the longer the beating, the higher the tensile strength and rigidity of the finished board.

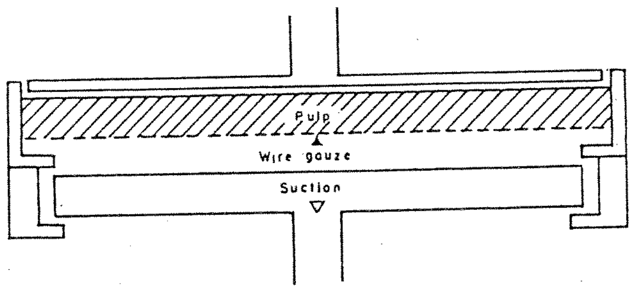
6.2 Sheet making

There are three main methods for board sheet making, each of them gives a different type of board and affects the quality and performance in wear.

6.2.1 Direct drainage

The beaten fibre slurry is run into a tray with a wire gauze bottom. Water runs through the wire, suction being applied by vacuum pump to assist water removal. The wet sheet is then removed from the wire and goes to the press.

By this method, the slurry is kept thoroughly stirred and the fibers are therefore randomly oriented. Theoretically, such board should show very little directional effects in their strength and stretch. If the fiber content is too low and too much reclaim paper is used those boards show a tendency to delaminate.

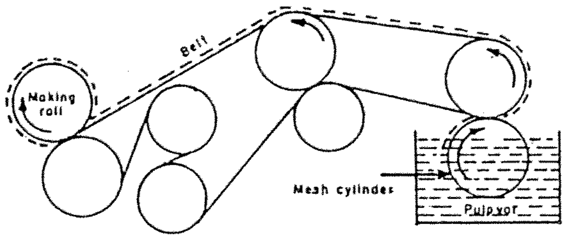


Direct drainage

6.2.2 Cylinder vat machine

The fibre slurry is fed on to a wire-mesh-covered hollow drum cylinder. Water drains through the wire, and a layer of fibres is picked up on the cylinder. This layer is transferred on a continuous belt to a making roll which has a grove along its width. Layer upon layer of fibre is transferred to the making roll until the layer reaches the necessary thickness. Then a spike is inserted into the grove cutting of the board. The board sheet goes then to the press.

Boards made by this method show a greater tendency to delaminate than those made by direct drainage.

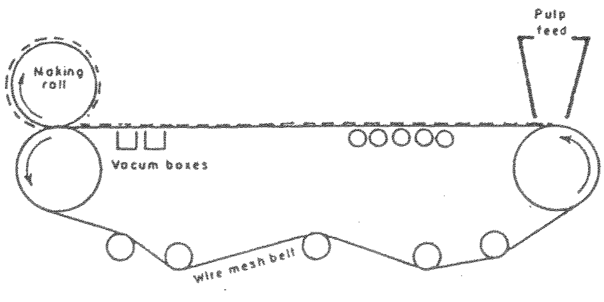


Cylinder vat machine

6.2.3 Fourdrinier machine

The fibre slurry is fed on to a continuous wire-gauze belt on rollers. As it is carried along the belt, drainage takes place through the wire, assisted by a vacuum process. The mat of fibres passes onto a making roll. This process is used to make board continuously.

In both the cylinder vat and Fourdrinier machine, the flow of the wet slurry tends to bring the fibres into a longitudinal position and although devices to check this tendency are used, the strength is always different along and across the sheet of the roll. These materials are marked with arrows to show the cutting direction.



Fourdrinier machine

6.2.4 Pressing, drying, finishing

Following the formation of the board, further processes are needed to consolidate and dry the material. These processes are similar for all kinds of boards and all methods of manufacturing.

The stack of sheets or roll, interweaved with felts to allow the water to drain away, is placed in a hydraulic press or pressing rolls. Pressing primarily removes water but also compresses the board into a denser and stronger material.

The pressed boards are then dried by hanging in ovens on a conveyor dryer.

The dried board can be splitted and finished by printing, glazing, pigmenting, etc.

7. Formula for leather Board

- ground leather scrap first in a mill and then between twin stones
- mix 30% leather scrap with 70% water, add some surfactant if the leather scrap is difficult to rewet. Chrome leather scrap should be retanned with vegetable tannin
- beat into slurry until the leather is thoroughly wet and in suspension.
- adjust the pH with ammonia to avoid early precipitation of the binder
- give some fat liquor depending from the required stiffness
- add 60% rubber latex or binder and mix

- add pigment if coloring is needed
- add alum to precipitate the latex on to the fibers
- transfer the slurry to the draining
- transfer the wet sheets to the press
- press at 80 °C and 90-100 bar
- dry in oven up to 20% water content
- dry at open air

Up to now, they have only limited use in footwear manufacture. Mixed boards containing waste or reclaim from textile fibers may not be classified under this group.

8. Thickness of fibreboards

The thickness of baords can range from 1.5 to 5 mm, but most are between 1.8 mm and 3 mm.

The maximum thickness for cellulose boards is 3.15 mm, only leather boards can go over that thickness, however, boards thicker than 5 mm show an important drop in cohesion.

The tolerances for the thickness of the board varies between manufacturers varies, but should be ± 0.1 mm

9. Requirements

9.1 Insole boards

TEST	VALUE	GUIDELINE A	GUIDELINE B	GUIDELINE C
Flexing resistance	number of flexes	100,000	50,000	10,000
Strength	tensile dry N/mm2	15	12	10
	tensile dry N/mm2	7	6	5
Moisture absorption and desorption	after 1 h in water drying	min 35% max 12 h		
dimensional stability	12 h at 70 °C	max 3 % linear		
rubfastness or scuff resistance	after 1000 rubs loss in mm3 max	50	75	100
on request				
heat resistance	at vulcanizing temp.	no damage		
stitch tear resistance	double hole N	70	60	50
rib adhesion peel test	N/rib min	14	-	-
shear test	N/25 mm rib length min	350	-	-
delamination	peel N/cm	5	4	3
	transverse splitting N/cm	8	5	3

A high quality footwear, army boots, safety boots

B medium quality footwear

C cheap footwear

9.2 Seatboards

The choice of the correct grade and thickness of seatboard is influenced by:

a) the height of the heel
b) the method of heel attachment
c) the kind of insole construction
d) the upper design

The performance requirements for seatboards are split into three grades, based on the tensile strength and heelpin holding strength of the board.

T E S T		RECOMMENDATIONS		
		Grade 1	Grade 2	Grade 3
Tensile strength	dry N/mm2	50	40	30
	wet N/mm2	25	20	15
Heelpin holding strength	dry N min	1080	880	690
	wet N min	980	780	590

Tensile strength is measured dry and wet after 6 hours soak in water. This test provides information on the structure of the material. The heelpin holding test measures the ability of a board to hold the heelpin and to prevent its head being pulled through the board . The wet test is to perform to articles that are to receive heavy wettings, for example, sandals.

Further, good shoemaking practice is to follow in the positioning of the pins, the position of the shank, the kind and dimension of the grindery and the properties and dimensions of the heel material.

9.3 Stiffener board

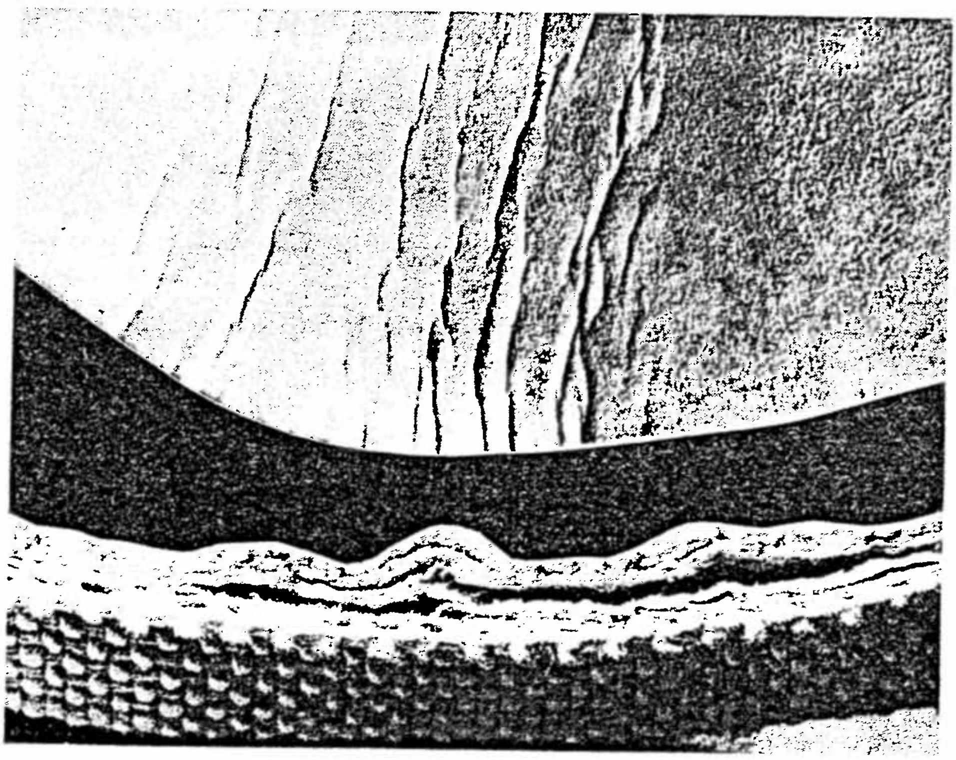
These boards are more and more replaced by non-woven materials. Stiffener boards should have the same quality requirements as non-woven stiffeners.

INSOLES

Some defects in wear

Microbiological breakdown

: Importance of scuff resistance



Delamination and wrinkling

pictures from SATRA

II. TOE PUFFS AND STIFFENERS

Toe puffs reinforce the toe end of the shoe upper, and stiffeners retain shape and provide support at the back of the shoe.

1. Types of toe puff and stiffeners

The wide range of footwear, from lightweight fashion shoes to heavy workboots, demands a correspondingly wide range of reinforcements to satisfy practical and aesthetic needs.

Furthermore, a wide range of materials is necessary as the result of their differences in manufacturing techniques, with their different demands on the properties of shoe components. Innovations will continue with the aim of producing the most acceptable reinforcement of toes and backs at the lowest possible cost.

Table 1

Types of Toe Puffs and Stiffeners

Material	Properties
leather	strong, durable puff but rather bulky must be thoroughly wetted for pliability and takes a long time to dry out.
leatherboard	more uniform than leather but rather bulky
celluloid	sleek and firm, but difficult to prepare
nitrocellulose impregnated fabric	sleek and firm, but easier to handle
paint-on	inexpensive, but often messy and variable in performance
thermosetting	very hard puffs, need special machine

impregnated fabric - heat reactivated	clean and easy to apply, good on most types of shoe, need machine and control
print-on	smooth, sleek puff, strength depends from the coating
filmic	smooth puffs but limited in strength need reactivation
steel caps	for safety footwear

1.1 Paint-on liquids

Painting on a liquid, shellac or cellulose solution, is mainly applied on veldtshoe. Results vary with the degree of penetration and the amount of resin applied. There are problems of contamination of the upper and adhesion to the last.

1.2 Impregnated Fabrics

There are two types of impregnated fabrics for toe puffs: the thermoplastic and the solvent activated type.

Some toe puff materials can be either heat or solvent activated. The same substrates are used for both types: woven, non-woven, needle-punched and stitch bonded fabrics. Most of the substrates are non-woven, but there are still woven fabrics of the flannelette or swasdown type because they can pick up higher quantities of impregnation liquid.

There are also materials based on polyacrylates, EVA,PU or gutta-percha. The impregnation process is the same for the two types of materials. Metering to provide the correct amount of impregnant is essential.

If the impregnation is inadequate, the puff will not mold fully during bonding in the shoe factory. The resultant puff will be limp and weak and may also be more easily affected by moisture. On the other hand, if the substrate is excessively impregnated, the finished puff can be too hard and brittle.

Fungicide can be introduced during impregnation to improve rot-proofing resistance. The impregnating material should not include substances with high salt content to avoid salt spue formation.

1.2.1 The thermoplastic toe puff can be softened by heat and rendered sufficiently extensible and malleable to accept pulling over and lasting operations.

In the early stages of their development, heat-activated puffs were impregnated with PVA or polystyrene and coated with latex, rubber or polychloroprene adhesives. The new types are impregnated with hot-melts but need higher activation temperature. (110-140°C or 140-160°C)

1.2.2 Solvent activated toe puffs

The material is impregnated with either nitrocellulose or polystyrene resins.

To produce nitrocellulose impregnated puffs, the base material is passed through a bath containing nitrocellulose in a water-miscible solvent, such as acetone or alcohol, and then through a water bath to extract the solvent. As the solvent is extracted, the nitrocellulose is precipitated within the fabric. In the shoe factory, the nitrocellulose puff is softened in acetone, with eventually other solvents to control the speed of activation.

Production of polystyrene impregnated puffs is similar to that of the nitrocellulose type, but the activation solvent in the shoe factory is then toluol.

For footwear without lining and to prevent the puff from sticking to the last, water based polystyrene-plasticizers dispersion are used and pre-coated on only one side of the material.

1.3 Print-on Hot-Melt Resins

The print-on hot-melt toe puff is a further development of the paint-on liquid type in which the solvent has been eliminated.

Examples are:

1.3.1 The Tru-line process of the BUSM, which uses a polyamide resine in rod form, which is extruded, melted and injected into a mould cavity adjacent to the flesh side of the leather.

1.3.2 The transfer sheet method which incorporates a thermoplastic polyamide film cast on release paper. On contact with a heated die - in the shape of the required toe puff - the resin is melted and transferred to the upper.

1.3.3 The Sigma method, in which a thermoplastic resin is injected into a mould, in the shape of the toe puff, and automatically applied to the upper before it sets. In this application, the dangers of insufficient fusing or inadequate activation are overcome because an evenly coated plastic film is formed on the surface of the upper.

1.4 Filmic puffs are a further development of celluloid impregnated puffs and are made from polymers such as ABS (acrylonitrile butadiene styrene) or EVA. The filmic puffs are thermoplastic and have a heat sensitive adhesive activated in the bonding press in the same way as the impregnated types are activated.

2. Recommended Uses

The following recommended uses of various types and thickness of puffs are given as guidelines.

Solvent-activated fabric-based puffs:

1. Cellulose-nitrate impregnated

0.7-0.9 mm	Women's shoes
0.9-1.2 mm	Women's heavy duty shoes and boots and children's and men's light shoes
1.2-1.6 mm	Men's and boy's shoes
1.6-2.0 mm	Men's heavy shoes, industrial boots, and sports shoes

2. Polystyrene impregnated

0.5-0.8 mm	Women's shoes
0.8-1.0 mm	Women's heavy shoes and boots and children's shoes
1.0-1.2 mm	Men's and boy's shoes
1.2-1.6 mm	Men's heavy shoes and sports shoes
1.6 mm and over	industrial boots

Thermoplastic polystyrene-impregnated fabric puffs:

0.4-0.7 mm	Women's and children's shees
0.7-1.0 mm	Women's heavy shoes and boots Children's and men's light shoes
1.0-1.2 mm	Men's and boy's shoes
1.2-1.5 mm	Men's heavy shoes, industrial boots, and sports shoes

Print-on Puffs:

0.5-1.0 mm	Women's shoes
1.0-1.5 mm	Men's and boy's shoes

Filmic puffs:

0.5-0.7 mm	Women's light shoes and children's shoes
0.8-1.1 mm	Men's and boy's light shoes

Liquid puffs:	Children's sandals

3. Testing of Toe Puffs and Stiffeners

3.1 Working Properties

To be effective, toe puffs require the following working properties:

a) they must bond rapidly and consistently to the flesh (or back) side of a variety of upper materials.

b) they must have adequate stretch and conformability to permit clean lasting with any upper material, without the use of excessive pre-heating

c) puffs must not stick to either the fusing press upper plate or to the last.

3.2 Wearing Properties

The bond to the upper and the shape of the last must be adequately retained. This means it requires resistance to:

a) foot moisture

b) plasticizers from PVC coated fabrics, particularly in flow-moulded footwear if the puff is bonded during the flow-moulding process.

c) compressive force to fall-in and shape retention

d) small repeated distortions that can occur during normal wear

e) large distortions due to accidents or misuse

f) abrasion from toe nails

3.3 Current Test

3.3.1 Bond strength determined between puff and upper

The puff is fused to the upper using time and temperature conditions similar to those in the shoe factory. The puff is then peeled from the upper after a normal conditioning period (48 hours in climaroom). Ageing test are also carried out, after 14 days at 50°C, which speeds the migration of plasticizers and fats that may affect the adhesive, after 6 hour immersion in water and peeling on wet sample.

3.3.2 Extension at break to check the isotropy of the material and also its ability to stretch during lasting. This test is combined with a lastometer test in which the material is fused on a lining.

3.3.3 Dome Test and Shape Retention

Long term shape retention is measured on the dome plastimeter by recording the retention of the cap height in function of time, and of ageing.

3.3.4 Collapsing load is measured by determining the load needed to produce an initial collapse of the dome.

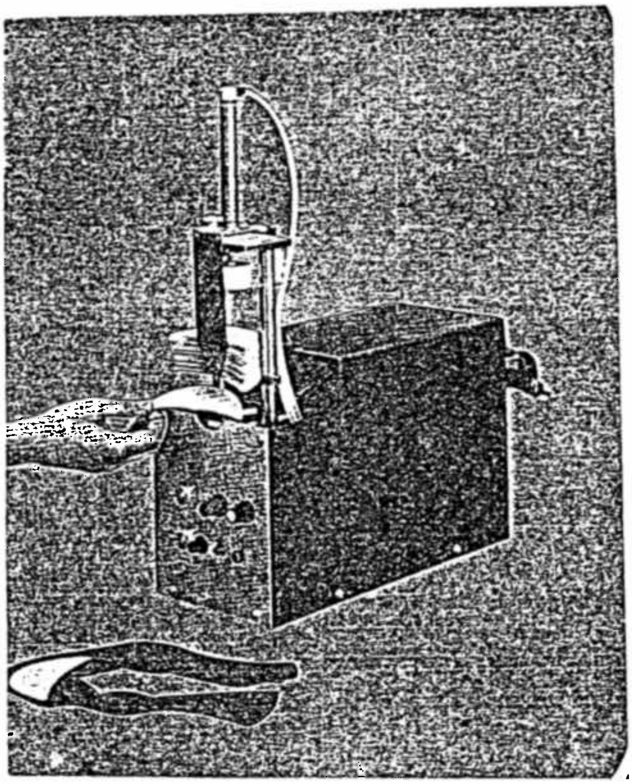
3.4 Guidelines

3.4.1 peelstrength min 6 N / cm both dry and wet

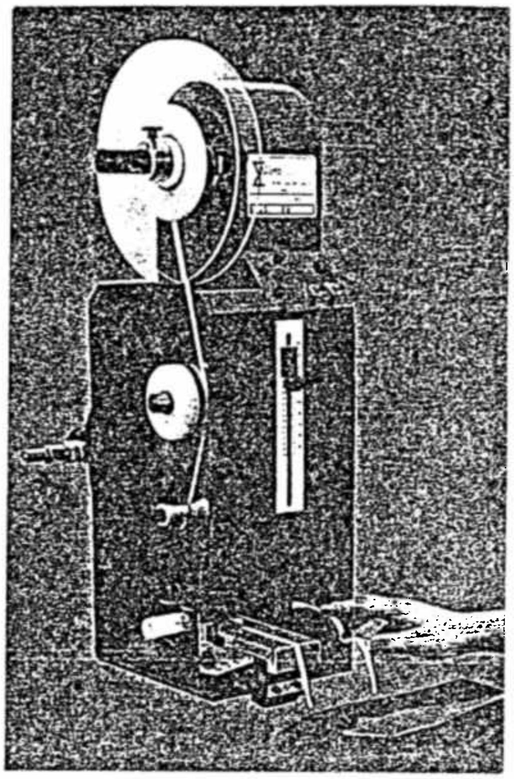
3.4.2 extension at break min 15%

3.4.3 shape retention 60 to 80 %

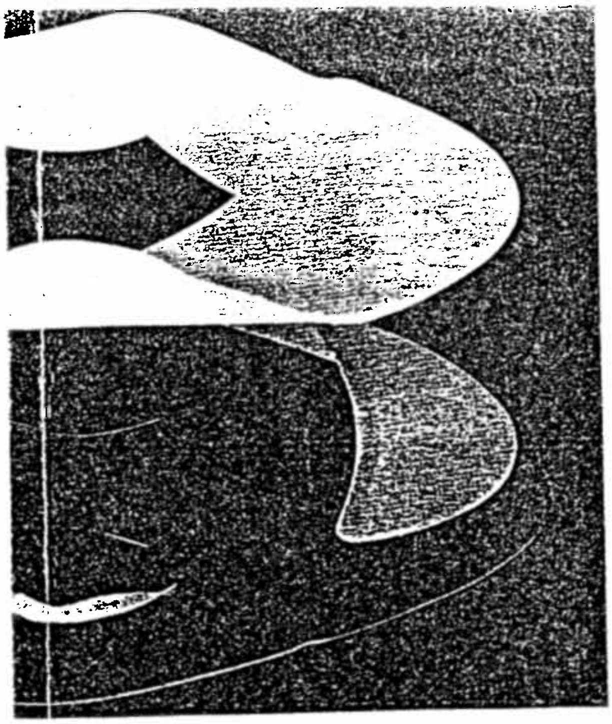
3.4.4 Dome collapsing load min 4 kg.



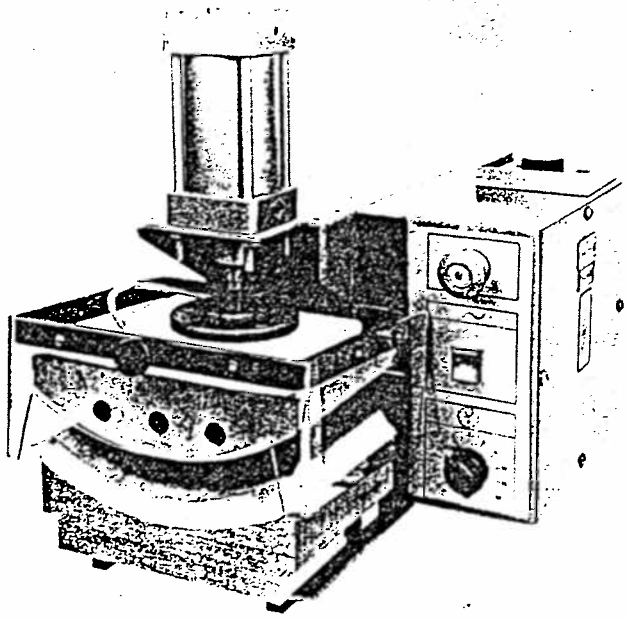
Thermoplastic toe puff
activator and dispenser



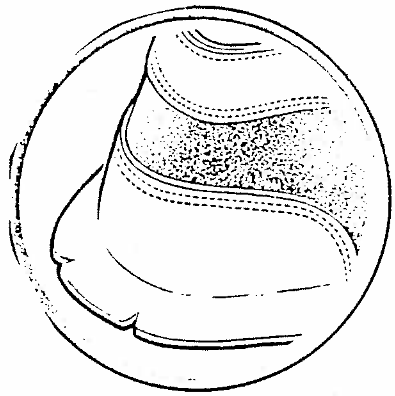
Automatic adhesive
tape dispenser

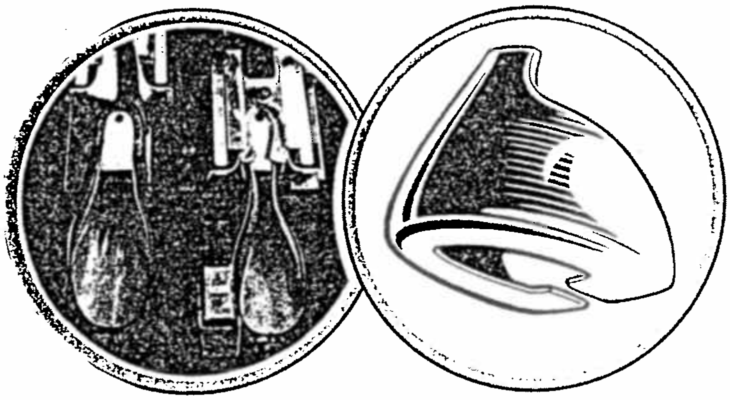


Thermoplastic
backlining

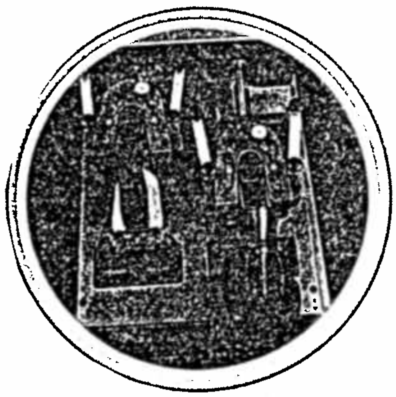


Toe-puff fusing press





For reactivation and premoulding of backparts of low or high heeled shoes



For reactivation and premoulding of backparts of veldschoen

III. SHANKS

The shank is one of the most vital components in a shoe. In providing essential support for the arch of the shoe, it has to withstand heavy bending and torsional stresses whilst maintaining accurate alignment of forepart and heel throughout all the stresses of the shoe's life. A shank is probably the most severely stressed component in a shoe.

There are mainly two types of shank : wooden and steel.

Wood is used in flat shoes, but in ladies high heeled shoes only steel is used, and this is fluted to give added strength.

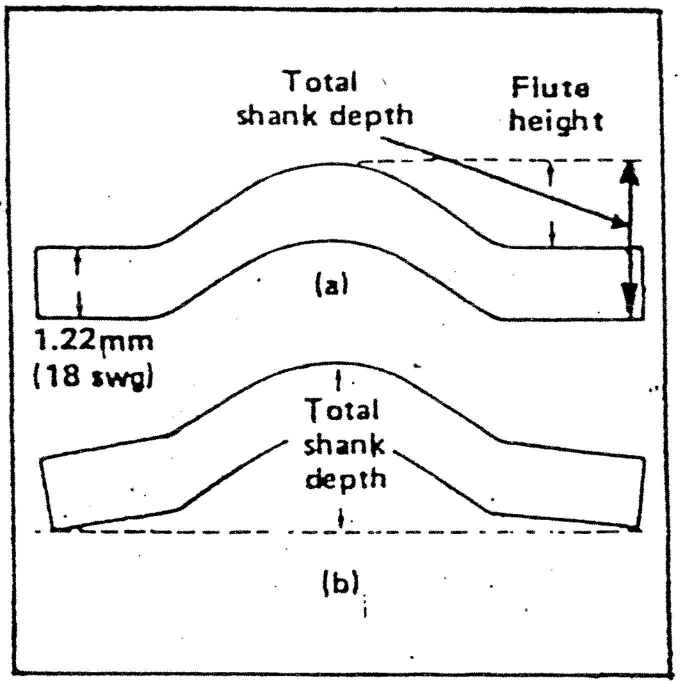
Steel shanks are manufactured from carbon steel, recommended is the types of steel corresponding to British Standard CS.50, this is a 0.50 - 0.55% carbon steel.

Shanks can be produced from wide strip steel, whereby the width of the strip is the length of the shank, or from narrow strips, where the length the strip is the length of the shank. In the rolling process to which steel is subjected at the mill, a direction is imparted and could give some a sinotropy.

The shanks are cut and pressed from the sheet steel and then hardened and tempered.

Two thicknesses of steel are commonly used : 1.2mm and 1.42mm, the width is usually 9.5mm or 12.7mm.

The shanks are produced to a fixed flute height 1.27mm or 1.9mm, the height depending on the strength of the shank required and the dimensions of the strip being used.



Shank cross
sections

After pressing, the shank can be oil-hardened and tempered or austempered. Austempering is an isothermal hardening process applied to the thin section of medium to high-carbon steel and is therefore ideally suited to the production of steel shanks.

The process starts with heating the shanks to 865^{o}C in a high temperature shaker hearth furnace and then quenching them in a molten salt bath at a temperature of 310^{o}C.

The shanks are then washed to remove any salt deposits and finally dried in hot air to give a clean, bright blue finish.

The austempered product is accurate in shape, consistent in strength, and tougher than that obtained by oil-hardening and tempering.

Performance Evaluation

Most shank breakages in wear occur at, or close to, the heel breast and are now thought to be caused almost entirely by the fatigue action of repeated stresses exerted on the back part of the shoe during walking.

The major factor affecting the stresses on the shoe back part is the height of the heel on the shoe, a higher heel imposing greater stresses on the shank, thereby reducing its fatigue resistance.

Other factors, such as the shape of the heel and heel spring are important but have less effect than heel height.

Shank performance can be evaluated by a stiffness test and a fatigue test, but none of those tests takes account of incorrect positioning of a shank within a shoe and most of the accidents happen because of wrong positioning.

Positioning of the Shank

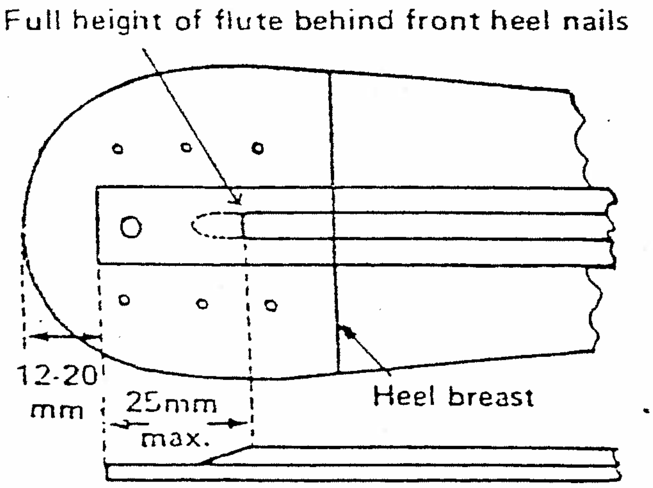
The strongest part of the shank (that is the fluted portion) must be positioned at the heel breast.

The full height of the flute should end no more than 25mm from the back edge of the shank.

No reduction in width and no cut-outs should be allowed in front of this point, except at the extreme front end.

The distance between the front of the flute and the front end of the shank should be as short as possible, particularly on shoes with a forepart platform construction.

The figure below shows the correct positioning of the shank.



Heel failure due to weak backseet and wrong positioning of shank

IV. H E E L S

1. Injection-Moulded Heels

The two main styles of heel made by the injection-moulded process are the cavity moulded "chunky" heels - for both men and women - and stilleto heels.

1.1 Chunky Heels

The most common materials used for this type of heel are polystyrene (high impact resistant), ABS, polypropylene, and expanded plastomeres. Nearly all chunky heels used nowadays are moulded from high impact, toughened polystyrene and are either white or self-colored. The best grades must be used so as to avoid brittleness and cracking on attachment.

The use of ABS in chunky heels has been limited to heels intended for electroplating. As ABS is harder than most grades of polystyrene, heel-attaching pins require greater pressure for insertion.

Polypropylene has excellent impact and fatigue resistance, a better nail and pins tightness, but often show a low dimensional stability; a higher shrinkage after moulding and a low compression resistance. Expanded plastomeres have the advantage of lightness but need a solid insertion in the seat to take the grindery attachment.

Plastic chunky heels are produced by conventional injection moulding using the techniques in a multi-cavity mould. Heels are injected close to the center of the seat surface. After release from the mould, the heels are immersed in water for cooling.

1.2 Stilleto Heels

For stilleto heels, the most widely used material is polystyrene, but other materials used include ABS, polypropylene, polyacrylates, polyamides and expanded polystyrene. They can also be made from mixtures of polypylene/polystyrene, or in two components - compact polypropylene external and expanded internal - or PU/ABS/polyamide.

Most of the strength of a stilleto heel is in its steel reinforcement. Nevertheless, a plastic compound with adequate impact and fatigue resistance must be used to prevent stem breakage.

Breakage in wear occurs in two ways: either by a sudden sharp impact or wrench, such as in stepping of a bus or getting caught in a grating or kerb edge, or else by fatigue built up by the repeated small impacts of normal walking. To combat both types of failure, the plastic must have goof fatigue resistance, and brittle grades must be avoided. Like chunky heels, plastic stilleto heels are produced by conventional injection-moulding techniques.

Steel rod reinforcing inserts are either moulded in or inserted after moulding.

Many different types of reinforcing insert are used, but steel is the most satisfactory and allows for extreme heel shapes. Medium-hard steel is suitable for most heels, and if failure occurs in wear, the inserts usually bend rather than break, minimizing injury to the wearer. Some grades of hard steel that have not been correctly heat treated will break readily, usually when the plastic breaks.

Three types of steel inserts are suitable for stilleto heels:

- solid rods, drilled at the tip,
- tension pins
- solid rod inserts with top-pieces attached

2. Built Heels

Traditionally, heels were produced using all-leather lifts, but since the development of fiber board, heels are now mainly made from a combination of leather and fiber board or, sometimes, all board.

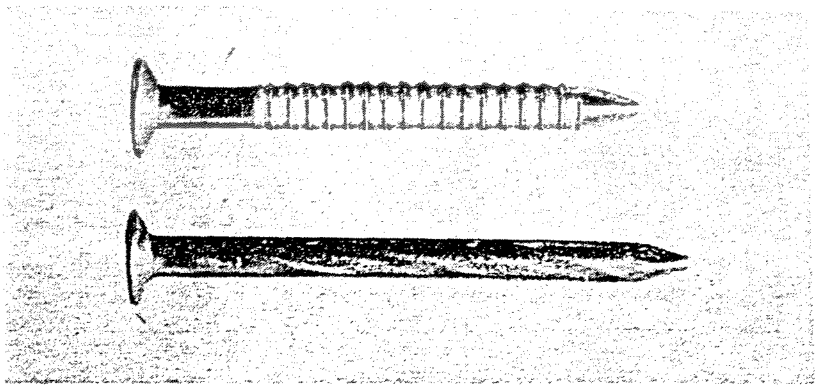
3. Turned Wood Heels

Heels are normally made by turning on a copying lather from well seasoned dry timber. The wood used is mainly beech with a close fine grain.

Although wood heels have largely been replaced by plastic heels, they are still used widely because of their low price.

Wood heels have poor shape stability, tendency to split and are difficult to repair.

To give satisfactory pin holding strength in wood heels eclipse pins or nails are used. Buttress pins recommended for plastic heels, should be avoided for wood heels because the barbs of the shank can ream on the wood on insertion and result in poor holding strength. The rifled shanks of eclipse pins compress the wood and give a better hold.



Buttress (top) and eclipse nails

4. Heel Attachment

The faulty attachment of a heel to a shoe is one of the more serious causes of wear complaint because it can lead to personal injury. The correct method of attachment must, therefore, be used for a particular style, and the heel must be secure in the finished shoe.

Two basic methods of attaching heels are used: the inside method and the outside method. With the inside method, nails, staples, or screws are inserted from the inside of the shoe. With the outside method, the heel can be attached in a number of ways, but in each case, the nails or rivets are inserted into the insole from the outside, often clenching over a last plate.

The outside method is used exclusively for shoes with low, broad heels, such as men's town or walking shoes made by the welted method, or for work boots. The inside method is universally used for fashion shoes.

To assess the strength of an attached heel, the heel pull-off test can be used, whatever the form of attachment - nails, staples, or centre screw. The test measures, in a stensile machine, the load required to pull the heel off backwards. The heel is normally pulled off backwards because most wear failures are due to the heel becoming detached at the breast first.

The forepart of the shoe is fixed into one jaw of the tensile machine and the heel into another by means of a swivel pin and cradle. The load needed to remove the front nails or staples is recorded as the heel is detached.

The recommendations for the heel pull-off load are shown in Table 1. The values have been obtained by comparison with known wear failures.

TABLE 1

HEEL ATTACHMENT RECOMMENDATIONS

Heel Pull-off Load (kg)	Comments
Below 30	Definitely troublesome
30-40	Likely to cause problems
40-50	Doubtful performance
50-60	Probably satisfactory
60-80	Adequate for most styles
Over-80	Good safety margin

For adequate attachment,a load of at least 50 kg is required.

Because the test automatically compensates for different heel heights, you should remember that, although a combination of nail length and reinforcement may give an adequate test result on a low heel, it may fail when used with a higher heel. Table 2 shows typical loads required to remove the heel with various forms of reinforcement on the insole.

TABLE 2

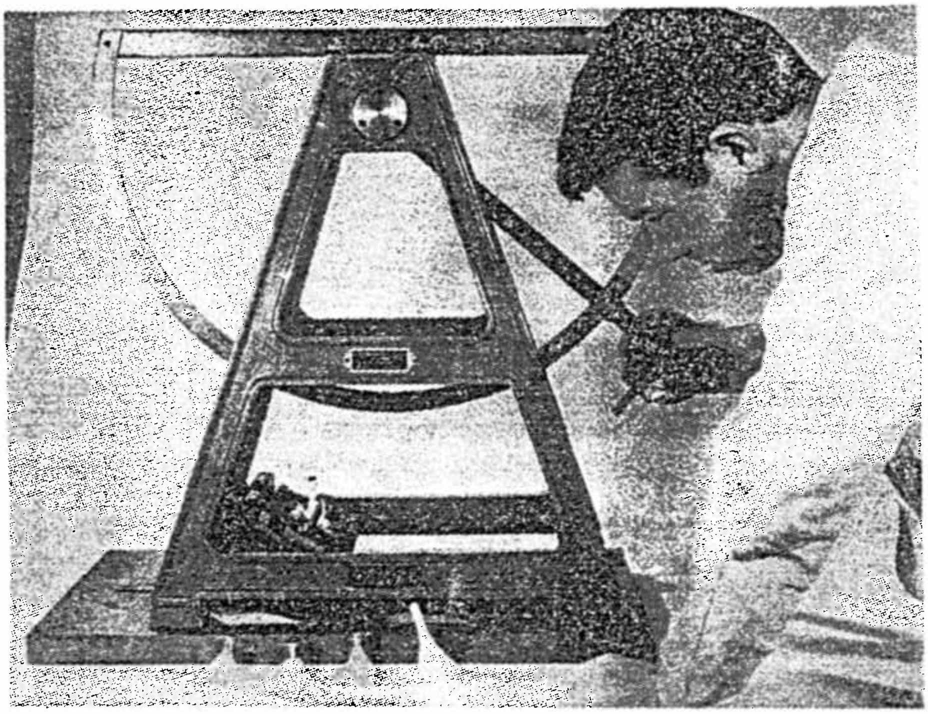
TYPICAL ATTACHMENT LOADS

Type of Attachment (polystyrene heel)	Typical Pull-off (load (kg)
Staples	20-40
Staples + fibre shim	60-140
Buttress nails	40-100
Nails + washers	80-120
Nails + fibre shim	100-120
Nails + metal shim	100-150
Centre screw + staples	30-50
Centre screw + nails	60-70

5. Performance Evaluation

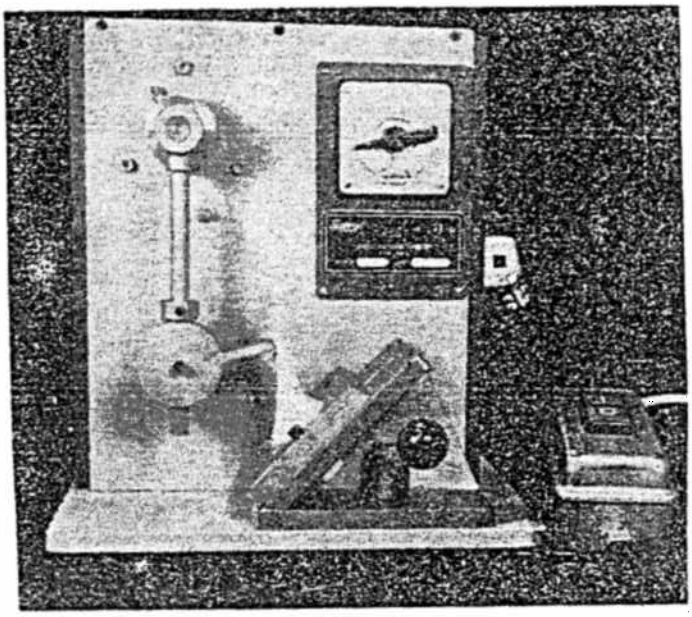
Two tests determine the resistance of the heel to breakage in wear: the impact test and the fatigue test. Both are more relevant to the slender heel than to the broader type of heel, having been developed and used successfully during the stilleto era.

The heel impact test measures the impact energy required to break the heel stem by applying impacts of increasing strength to the heel tip until fracture occurs, as shown in Fig. 3.



Heel impact test

The heel fatigue test applies small blows repeatedly to the heel tip, as shown in Fig. 4. The number of blows required to break the heel is measured. In both tests, the heel base is securely held in a metal mould.



Heel fatigue test

A splitting test is used to determine the likelihood of a heel splitting when heel or top-piece attaching grindery is inserted. A number of pins are inserted, closely spaced, near the edge of the heel, and any splitting is observed.

A fourth test involves measuring the load required to pull a standard heel pin out of the heel. This is essentially a test for the pin holding quality of the heel material, but it will also indicate if enough thickness of heel material is available to accommodate the full length of the heel-attaching grindery, for example, in a cavity-moulded heel.

Performance Requirements

Due to the wide variety of heel types and due to the fact that the fatigue and impact tests are largely unnecessary on very broad heels, the performance requirements are split into two parts.

Slender heels : These are defined with stems 3 cm or less across. Table 5 shows the requirements.

TABLE 5

Performance Requirements - Slender Heels

Property	Minimum Requirements
Impact resistance	No damage after 8 blows
Fatigue resistance	No damage after 2,000 blows
Heel pin holding	75 kg minimum

Clumpy heels : These are defined as heels with stems greater than 3 cm across in any direction. Table 6 shows the requirements. However, if there are any suspect features in materials or designs, such as the use of cellular plastics or cut-outs, heels should be tested against the slender heel requirements.

TABLE 6

Performance Requirements - Clumpy Heels

Property)	Minimum Requirements
Resistance to splitting	Freedom from splitting when 12 pins are inserted
Heel pin holding	75 kg minimum

Design Recommendations

In addition to the formal specification, the following design recommendations will help in the production of heels that will pass the specifications.

Heel Seat: The seat should be cupped (dished) to fit the surface of the lasted upper as closely as possible. If necessary, the seat may be recessed to take the shank flute, particularly on a sling-back style of shoe. As a general guide, the amount of cupping and/or recessing should be arranged so that the shank is clamped securely between heel and insole without damage to the heel breast.

Cavity-moulded heels: There are three main requirements for cavity moulded heels.:

1. There should be at least 10 mm of plastic at the seat into which the heel-attaching nails can be driven.

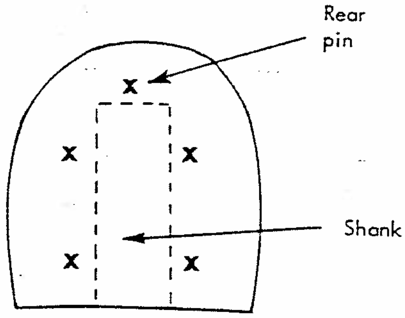
2. To prevent the "pastry cutter" effect on the top-piece, the walls of the heel should be no less than 5 mm thick at the tip. This should be increased to 10 mm at the back edge to prevent worn top-piece from collapsing into the cavity.

3. If the cavity is more tham 30 mm across in both directions at the top-piece, a reinforcing rib or centre pillar may be required to prevent the centre of the top-piece from collapsing into the cavity.

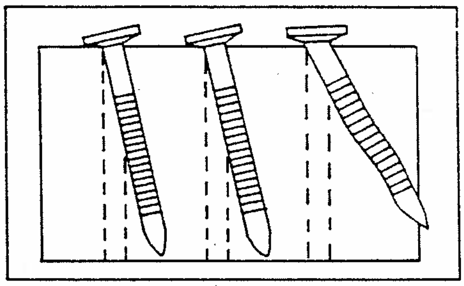
Slender heel reinforcement: The need for reinforcement of a heel will depend on its height, its shape, and the material from which it is made. Higher heels are more likely to require reinforcement than lower ones.

As a guide for solid polystyrene, reinforcement will normally be necessary if the heel stem is less than 15 mm across in any direction.

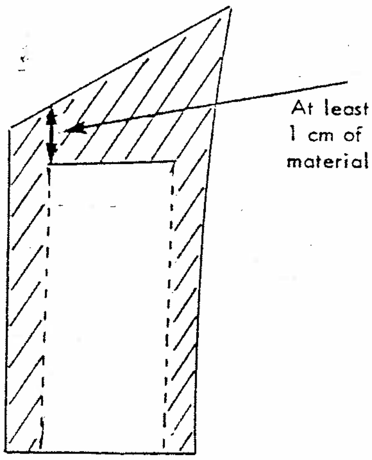
To reinforce a slender heel, a steel insert of adequate dimensions should be used to prevent fracture of the heel plastic. To be fully effective, the top end of the insert should be surrounded by solid plastic.



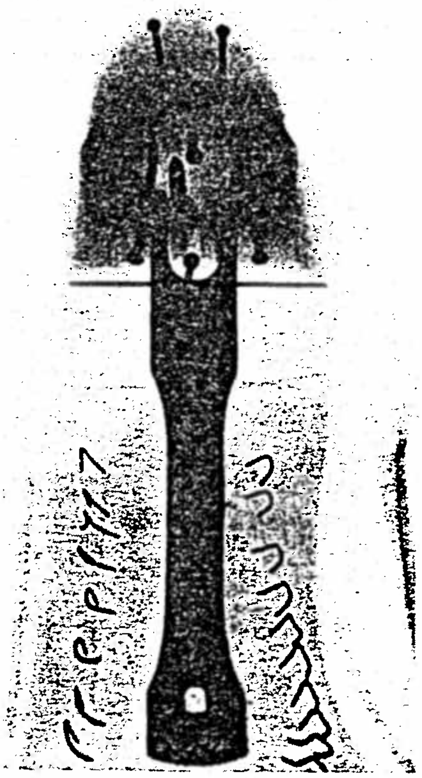
—5 pin grouping: the rear pin position will decide how far the shank can extend behind the heel breast.



: Nail deflection



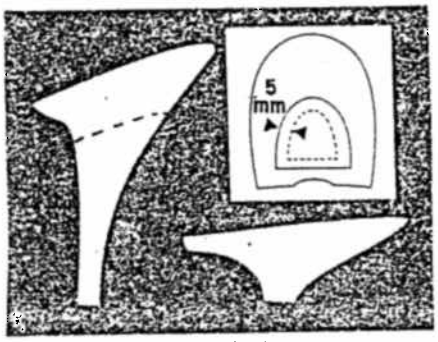
—The heel top should be no less than 1 cm where the heel pins are to be inserted.



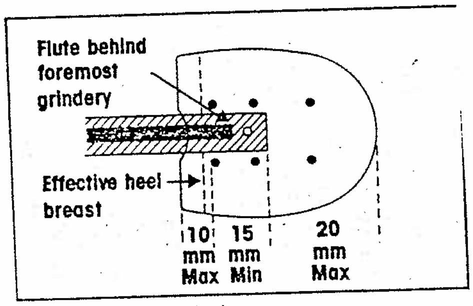
—X-ray photograph of a forked shank showing it has been positioned too far forward. The heel breast is indicated by the dark transverse line.

—Summary of Requirements for Pin Attached Heels

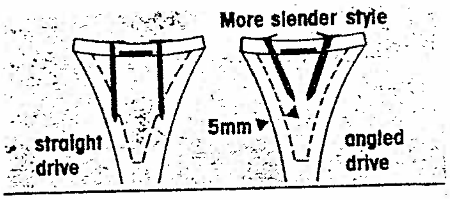
Requirement	*Heel type*	*Specification*
Choice of Pin	Wood	Eclipse
	Plastic	Buttress
Heel Top Thickness	Moulded Plastic	At least 10 mm
No. of Pins	Wood/Plastic	6 if possible or 4
Distance of front pins from heel breast	Wood/Plastic	Not more than 10 mm
Distance between pins	Wood/Plastic	Transverse and longitudinal distances between pins as great as heel base area will allow.
Distance of rear pins from heel breast	Wood/Plastic	Rear pins as close to back as allowed by heel shape and base area.



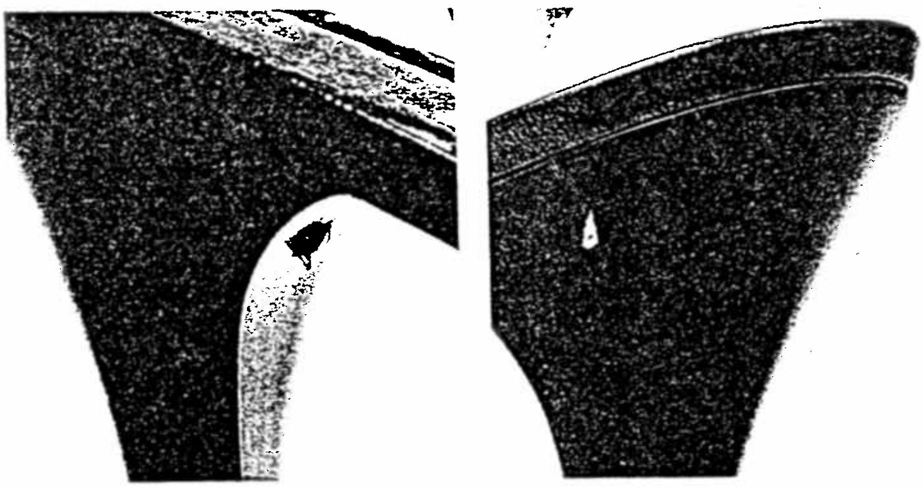
: Plastic area available



: Ideal positioning

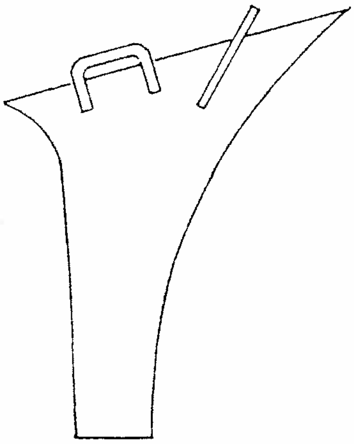


: Straight and angled nail drive

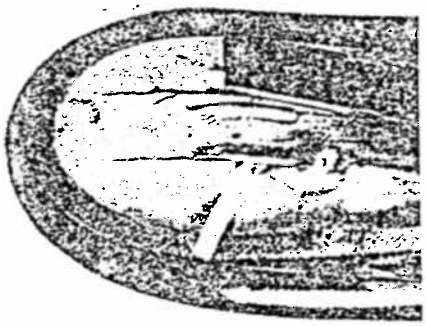


: Heels damaged by nail deviation

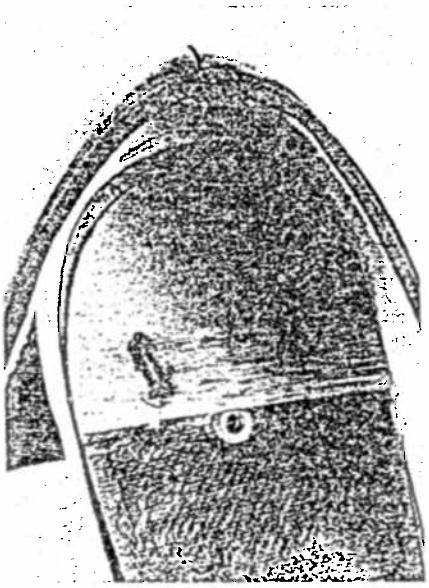
STAPLE HEEL ATTACHMENT



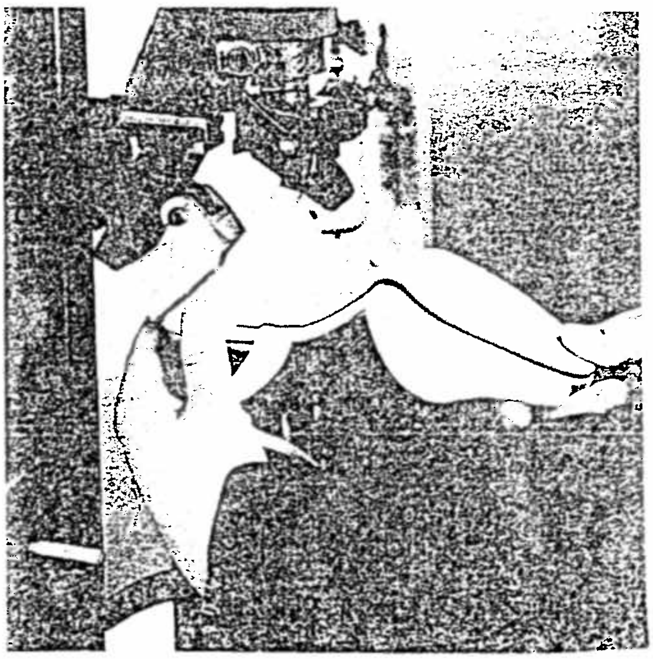
—Showing staples angled to prevent them emerging from the heel.



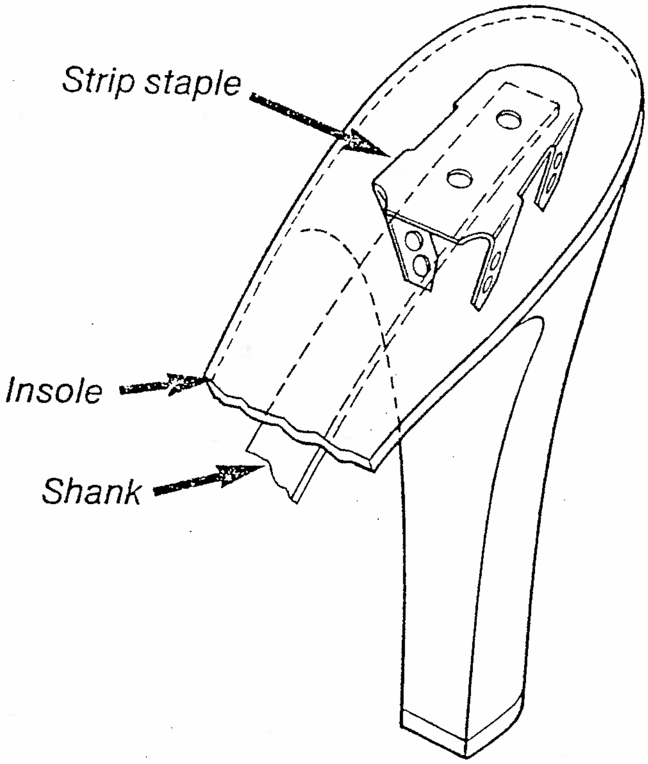
—Typical example of failure caused by the rear staple striking the shank and not entering heel effectively.

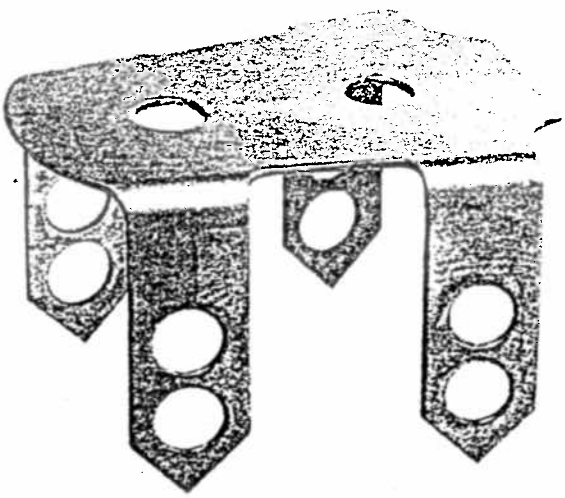


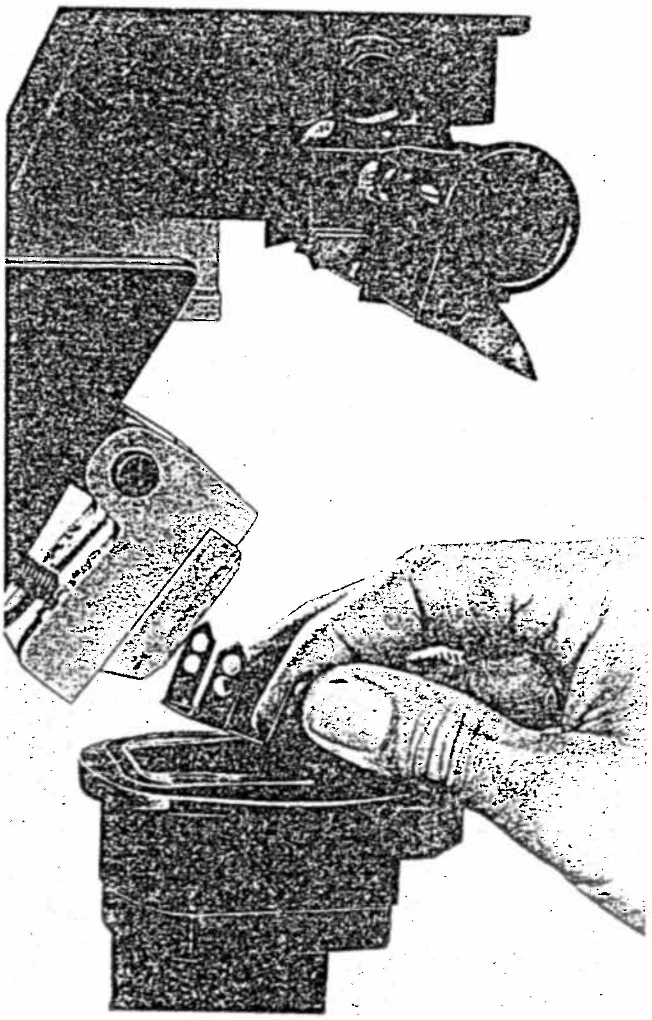
—The use of a shim can improve the strength of staple attachment of the heel.



STRIP STAPLE HEEL ATTACHMENT







V. HEEL TOPS

Heel tops are normally produced in:

- thermoplastic polyurethane
- polyamide
- PVC
- Compound rubber/polypropylene

1. Thermoplastic PU

The polyester type is usually used because it is cheaper and shows good resistance, except the resistance to cold for which the polyether type is preferred.

The recommended hardness is:

Shore D 75 for very small heels without metallic insert
Shore D 65 for any heel with or without metallic insert
Shore D 55 for men heels

2. Polyamide (Nylon 6)

Polyamide is more rigid than PU, but more slippery. It has a good abrasion resistance but produce burr.

3. Polyvinylchloride

This is the cheapest material, it is brilliant and glossy, very slippery and sensitive to temperature variations.

The recommendedhardness is Shore d 70

4. Rubber/Propylene Compound

This is also a low price material, its quality will depend from the amount of rubber scraps used. It is easy to mould, but has a low abrasion resistance.