Paper Code and Title: H09TC Textile Coloration and Finishes

Module Code and Title: H09TC03 Techniques for Dyeing Textiles

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TECHNIQUES OF DYEING TEXTILES – FIBRE, YARN & FABRIC – METHODS, ADVANTAGES, APPLICABILITY AND MACHINERY INVOLVED

1. Introduction

Dyeing is the process off beautifying textile products by applying colour. Colours can be applied at different stages of the textile production process. Quality woollen goods for example are frequently dyed in the form of loose fibre, but top dyeing or cheese dyeing is favoured in treating worsteds. Manufacturers prefer piece dyeing, which allows stocking of white goods, thereby reducing the risk of being overstocked with cloth dyed in colours that have not been ordered.

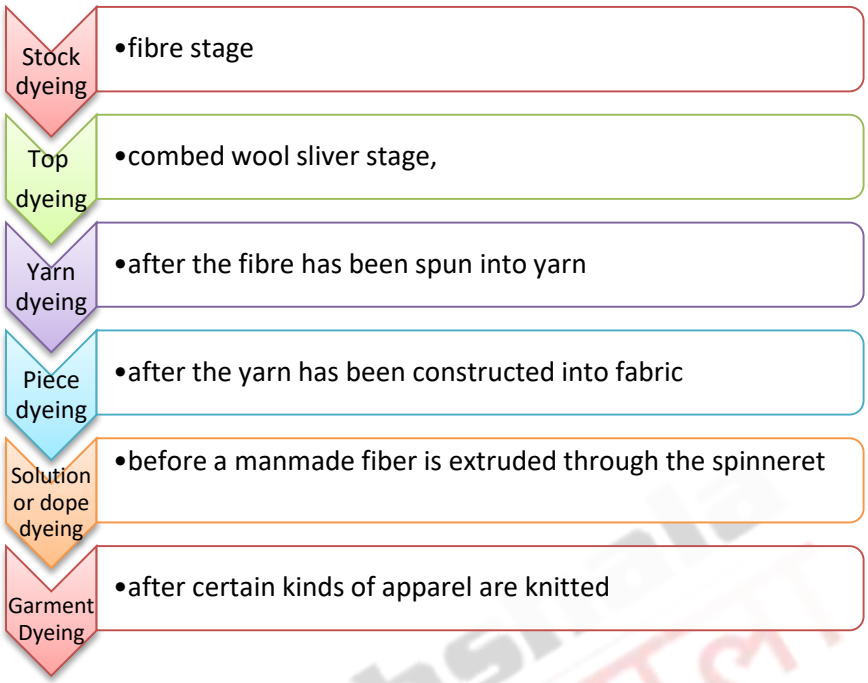
2. Learning objectives

- To understand the various methods of dyeing fibre, yarn and fabric
- To get an insight into the advantages and applicability of each method
- To learn about the machinery involved in dyeing

3. Methods of dyeing

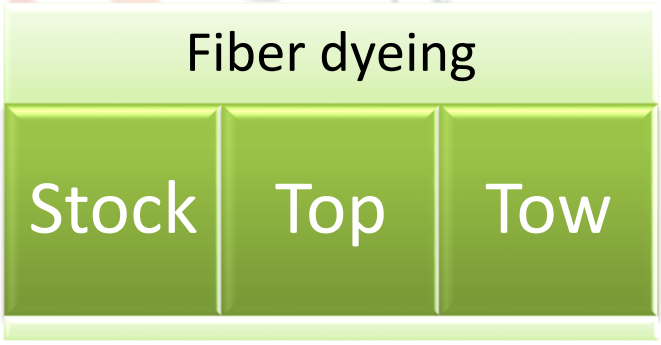
Textiles may be dyed at any phase of manufacturing of textile product. It may be coloured as fiber, as yarn, as fabric or a finished product including garments and apparels.

The range of methods include:-



3.1.Fiber dyeing

The process of dyeing fibers before they are spun into yarns are called fiber dyeing. Fiber dyeing includes



3.1.1. Stock dyeing refers to dyeing raw fibers or staple fibers, also called stock, before being spun into yarns.

There are two methods. In the older and common method the packed fibers are removed from the bale and put in large vessels and dye is circulated through the fibers at high temperatures.

In the newer method, bale dyeing, the bale covering is split on all sides, and placed in a specially designed machine , and the dye liquor is forced through the bale of fibre. This method saves time and labour cost and is suitable for wool and manmade fibres.

Though the dye liquor is pumped in large quantities through the bale, it may not dye the entire bale and some portions may be left without dyeing. However, in the next process of blending and spinning , the undyed fibres are mixed thoroughly with the dyed fibre that an overall even color is obtained.

3.1.2. Top dyeing – Top is nothing but the combed wool sliver. Top dyeing is the process of dyeing worsted wool fibers after it has been combed to straighten and remove the short fibers. This method is favored as the dye is not wasted on the short fibers that are removed during the combing process. Top is wound on perforated spools and the dye solution is circulated through it. This method results in very even dyeing.

3.1.3. Tow dyeing- The filament fibres before they are cut into short staple fibres are known as Tow and dyeing at this stage is called tow dyeing.

3.1.4. Features and Advantages of fiber dyeing

- Uniform dyeing is obtained as individual fibres get dyed without any resistance.
- The dye penetrates well into the fibres and so the problem of crocking is avoided.
- By mixing of the dyed and undyed fibres before spinning it is possible to get unique effects.

3.1.5. Limitation and Disadvantages of fiber dyeing

- Fiber dyeing is relatively costlier than yarn, fabric, and product dyeing.
- If not carefully handled there is possibility of the Loose fibres getting entangled .
- Dyed fibre loses its flexibility and so does not spin as readily as un dyed fibre.
- High percentage of fiber loss from dyeing and later yarn spinning, resulting in loss of colour also.
- Dyeing long before season begins carries risk of fashion changing.

3.1.6. Applicablity

Woolens are usually fiber dyed.

Yarns with two or more colors are normally fiber dyed for example, dyed(black) wool fibre might be blended and spun with un-dyed (white) wool fibre to produce soft heather like shade of grey yarn.

3.2.Solution pigmenting or dope dyeing

also called spun dyeing is the process for dyeing synthetic fibers. Pigments or insoluble dyes is added to the spinning solution before it is extruded through the spinnerets for producing synthetic filaments. This results in filaments that are fully impregnated with pigment coming out of the spinnerets in a one step process.

3.2.1. Advantages

- The color pigments become a part of the fiber and so solution-dyed materials are bright and have excellent colorfastness to all agents.
- Solution Dyed yarn is resistant to UV fading
- The colouring is uniform in solution dyed yarns and there is no variation from one lot to the other
- As no water is involved in the process it is environmentally friendly

3.2.2. Disadvantages

- It is practically impossible to solution dye yarn in small lots
- The tenacity of Solution dyed yarns are slightly lower
- This stage of dyeing is more costly, because the apparatus has to be cleaned carefully each time the colour is changed . Hence only limited variety of colours are produced.
- This stage of dyeing is not used for apparel fabrics as color decisions have to be made very early in the manufacturing.

3.2.3.Applicablity

It is mainly used for dyeing fibers which are difficult-to-dye , and for those fibers used in end products that require excellent colorfastness properties.

Solution dyeing is recommended for prime colors like black, yellow, green, red, and blue.

Solution dyed yarns are resistant to UV fading and dye bleeding so they are suitable for producing polyester and nylon sewing threads .

Package dyeing involves a lot of water and energy cost is also high so many manufacturers are changing to solution dyed yarns to reduce pollution.

3.3.Yarn Dyeing

The process of dyeing after the fiber has been spun into yarn and before they are woven or knitted into fabrics is referred to as yarn dyeing. In this stage of dyeing, the dyes penetrates to the core of the yarn.

There are several forms of yarn dyeing-

Among the various yarn dyeing methods Package and hank dyeing are the most frequently used methods. Polyester or polyamide yarns are always dyed in package form, Cotton yarns are mostly dyed in package form, and acrylic or wool yarn are dyed in hank form.

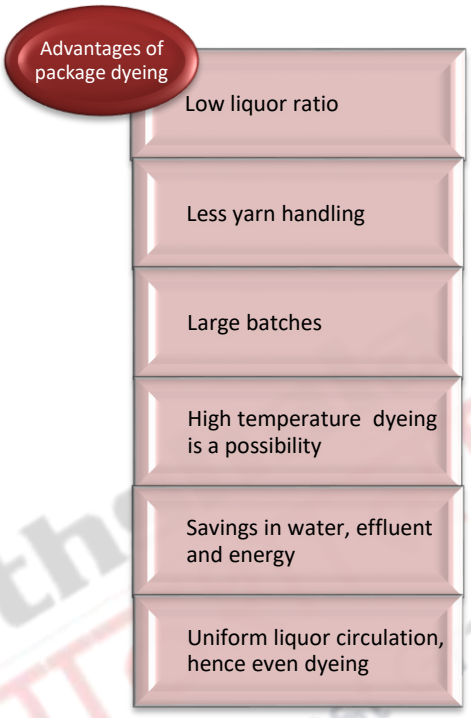
3.3.1. Skien dyeing

The yarns wound loosely into hanks or skein are hung over a pole and immersed in a dye bath. The colour penetration is excellent in this method and the yarns retain a softer, loftier feel. But the process is time consuming and expensive.

3.3.2. Package dyeing

In package dyeing yarns are wound on small perforated spool, cone or similar units and these packages of yarn are stacked on perforated rods in a rack and immersed in a tank and dyed under pressure, the flow of the dye bath can be altered from the center to the outside, and then from the outside to the center of the package. Package dyed yarns do not retain the softness and loftiness as skein-dyed yarns. While package dying is suitable for most materials, thick, high twist yarns

may not allow for good dye penetration, and materials exposed to outdoor environments experience fading and shade changes.



3.3.3. Beam dyeing

In beam dyeing the yarn is wound on a perforated warp beam and immersed in a tank and dyed applying pressure. It is economical than skein or package dyeing, but it is used only in the manufacture of woven fabrics. Knitted fabrics, are mostly produced from the cones of yarn, and are not adaptable to beam dyeing.

3.3.4. Space Dyeing

In this method, the whole yarn is not dyed it is dyed at intervals along its length. In knit- deknit method, the yarn is first knitted then dyed and then de knitted. Since the dye does not readily penetrate the areas of the yarn where it crosses itself, alternated dyed and undyed spaces appear.

Another method the OPI Space-Dye Applicator technique produces multi coloured space- dyed yarns. The yarns are dyed intermittently as they run at very high speeds through spaced dyebaths.

3.3.5. Features and advantages

- The primary reason for dyeing in the yarn form is to create interesting checks, stripes, and plaids with different-colored yarns in the weaving process.

- Yarn-dyed fabrics are usually brighter and richer in color.

3.3.6. Limitations and Disadvantages

- It is the **S**econd most costly dyeing method

- As the Dyeing is done before season begins there is risk of fashion changing.

3.3.7. Applicablity

This process is suitable when different colored yarns are required in the construction of fabrics (e.g. plaids, checks, iridescent fabrics).

3.4. Piece dyeing

The dyeing of cloth after it has been woven or knitted is known as piece dyeing or fabric dyeing. The various methods used for this type of dyeing include :

3.4.1.Beck dyeing

is used for dyeing long lengths of fabric continuously. The material is passed in rope form through the dyebath without any tension. This rope of the fabric passes over a rail onto a reel which immerses it into the dye and it draws the fabric up. This process may be repeated until the desired color strength is obtained.

3.4.2.Jig dyeing

The fabric in jig dyeing is held on rollers in open width and is passed through a deep dyebath until the desired shade is achieved. This reduces fabric tendency to crack or crease.

3.4.3.Pad dyeing

Pad dyeing is carried out with a machine called a dye pad. The fabric in full width is passed through a trough containing dye bath and then it is passed between two heavy rollers which force the dye into the cloth and squeeze out the excess dye. Then it is passed through a heat chamber to set the dye. Then the fabric is washed , rinsed and dried.

3.4.4.Jet

In the jet dying process, Fabric is placed in rope form in a heated tube where jets of dye solution are forced through it at high pressures. The fabric too moves along the tube. The solution moves

faster than the cloth while coloring it thoroughly. As only very little tension is applied this method is suitable for dyeing delicate fabrics . High temperature dyeing is also possible on most machines.

3.4.5. Beam dyeing

Beam dyeing for piece dyeing is practically identical to beam dyeing used for yarns. Fabric is wound on to a perforated cylinder and the dye is forced through the fabric layers. The fabric remains stationery. Beck and jig equipment are the commonly used methods.

3.4.6. Features and Advantages

- Compared to other stages fabric dyeing is very economical
- It is adaptable to both woven and knits
- Wastage can be avoided ,as colour decision is made finally after the fabric is manufactured, according to the fashion statement at that time.

3.4.7. Limitations and Disadvantages

- Limited to solid colours (except for cross-dye).
- In tightly twisted yarns and heavy woven fabric , Dye penetration may not be good .

3.4.8. Applicablity

It is the most suitable method for solid coloured fabrics .

3.5. Garment Dyeing

When the finished textile product such as apparels and garments are dyed, it is called garment dyeing. It is also called product dyeing. The types of apparel that can be dyed are mostly non tailored and simpler forms, such as sweaters, sweat-shirts, T-shirts, hosiery, and pantyhose. The effect on sizing, threads, zippers and snaps must be considered.

Garment dyeing is carried out by packing a suitable number of garments loosely into a large nylon net bag. A number of these bags are placed in large tubs containing the dye bath and are kept agitated by a motor-driven paddle in the dye tub. The machine is called a paddle dyer.

3.5.1. Features and Advantages

- Choice of colour is closest to fashion season.
- Elimination of material waste from prior processing waste
- Rejection is less

  No possibility of shade variation within the garments.
- Small lots of fabric could be produced at lower cost within less time.
- Compared to other methods capital investment is less
- In some cases, lower liquor ratio in garment dyeing requires lower water, steam and chemical consumption, hence lowers garments dyeing cost.

3.5.2.Limitations and Disadvantages

- Limited to garments of simple construction

- Tailored items, such as suits , cannot be dyed as garments because the difference in shrinkage of the various parts and linings distort and misshape the article.
- It is not suitable for far garments with lining, zipper etc as each part may be dyed differently. Labour intensive process
- Poor appearance

3.5.3. Applicablity

The process is suitable when all components (including threads) dye the same shade; for example, sheer pantyhose are knitted using tubular knitting machine, stitched with thread that dyes to the same shade, and then dyed.
Product dyeing is best for quick response. T-shirts, sweaters, and other casual clothing.

Active wear, Slacks, Jeans items, Panty-hose, Shirt , Terry items, Dresses, Leisurewear, Pullover, Skirt, Socks, Sweater are dyed using this technique.

4. Dyeing Machineries

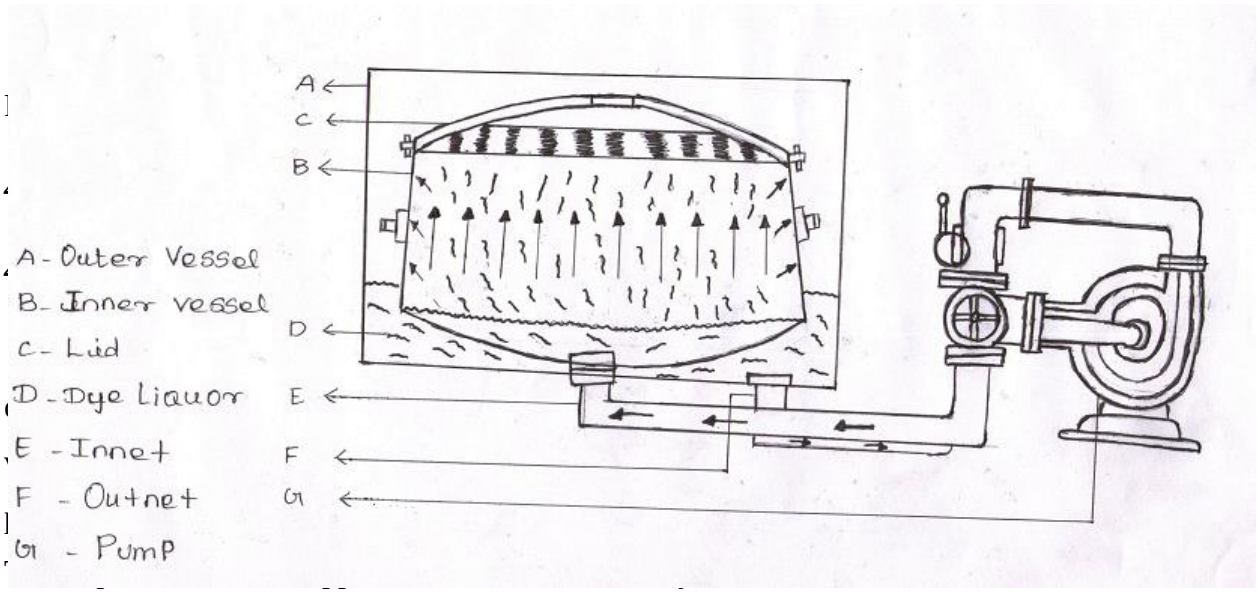
The conventional dyeing machines are constructed on the basic principle of either the movement of material to be dyed in a stationery dye liquor as in jigger, padding mangle or winch or movement or circulation of dye liquor through a stationary package of material as in cheese dyeing or beam dyeing machine and in some others, both the material and the dye liquor are kept in motion.

4.1.Fibre Dyeing Machine

4.1.1.Loose Stock Fibre Dyeing Machine

A commonly used machine for fibre dyeing is the conical pan with forced circulation. Fibers are packed in a conical vessel and retained by a lid which can be held down with a number of clamps. A flange at the bottom of container fits into a seating through which dye liquor is

circulated by a centrifugal pump. The fibre mass tends to become compressed in the upper narrow half of the cone, assisting efficient circulation. A gantry and traveling hoist are necessary to lift the container in and out.



the false bottom upward, and back in to the impeller compartment over the top, or in the reverse way. The volume of flow can be regulated. During dyeing the direction of the flow must be altered from time to time. When the current is in the downward direction the liquor does not come into sufficiently intimate contact with the portion of the hank upon the pole, and this would lead to higher mark unless the yarn is lifted whilst the flow is

Fig 1 Loose stock fiber dyeing machine

4.2.Yarn Dyeing Machines

4.2.1. Hussong Hank Dyeing Machine

The Hussong machine is the traditional apparatus for hank dyeing. It consists essentially of a frame carrying poles on which the hank are hung and which are lowered into the rectangular vessel containing the dye liquor. The liquor is circulated by means of an impeller through a perforated false bottom. The false bottom also serves to separate the steam pipe from the load.

The impeller rotates in opposite directions alternately so that the circulation is either from below the false bottom upward, and back in to the impeller compartment over the top, or in the reverse way. The volume of flow can be regulated. During dyeing the direction of the flow must be altered from time to time. When the current is in the downward direction the liquor does not come into sufficiently intimate contact with the portion of the hank upon the pole, and this would lead to higher mark unless the yarn is lifted whilst the flow is upwards. In practice the upward direction, is used for the greater proportion of the dyeing cycle as the liquor is compelled to come into uniform contact with every part.

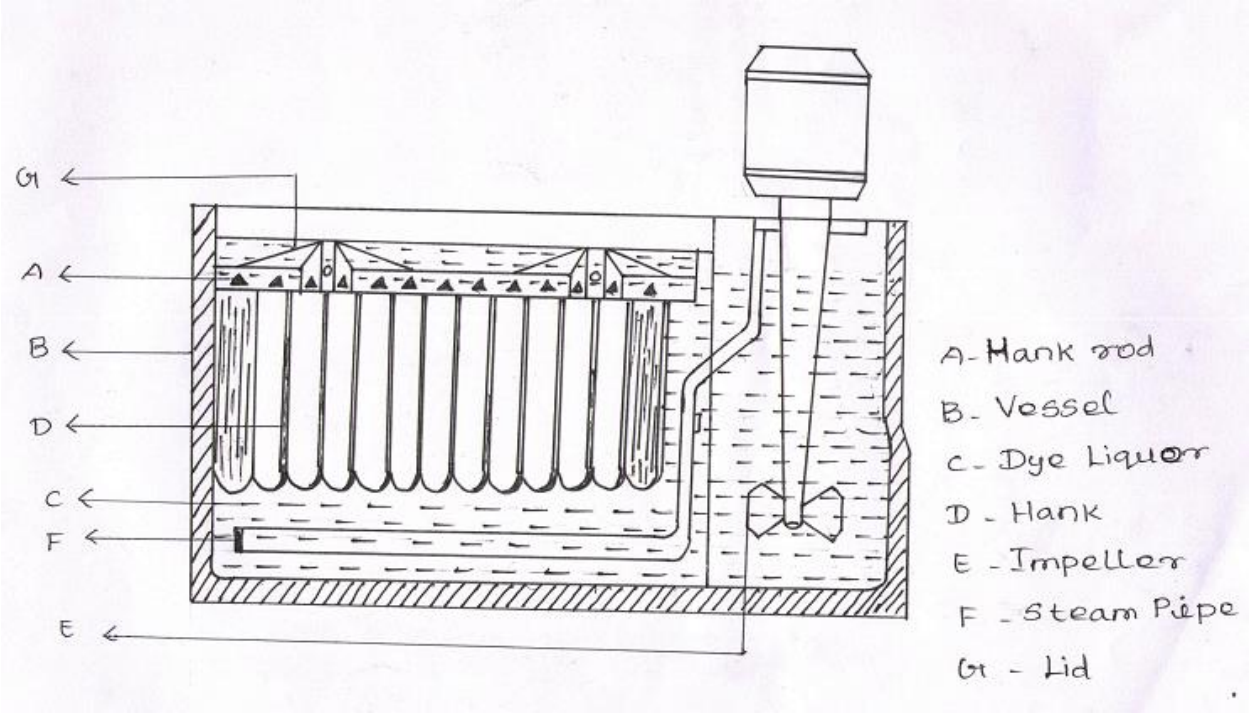


Fig.2. Hussong Hank Dyeing Machine

4.2.2. Package Dyeing-Cheese Dyeing Machine

Large amount of yarns are dyed in package form. Yarns are often wound in the form of cheese, cones, and cops. These machines consist of an outer vessel for containing the dye liquor which is

positioned with skeleton frame provided with number of perforated tubes in communication with a common central hollow base. The wound packages of yarn are dropped one above the other on these perforated tubes so as to enclose them tightly. The cover of the outer container is then secured .Dye liquor is with drawn from the outer container and forced up the tubes outwardly through their perforation and so through the yarn packages and back into the outer dye liquor container. The direction of flow of this dye liquor can be reversed automatically from time to time . These dye liquor circulating machines have in recent years been modified to the use of high pressure ,high temperature condition which is desirable for dyeing synthetic fiber yarns normally difficult to absorb dyes.

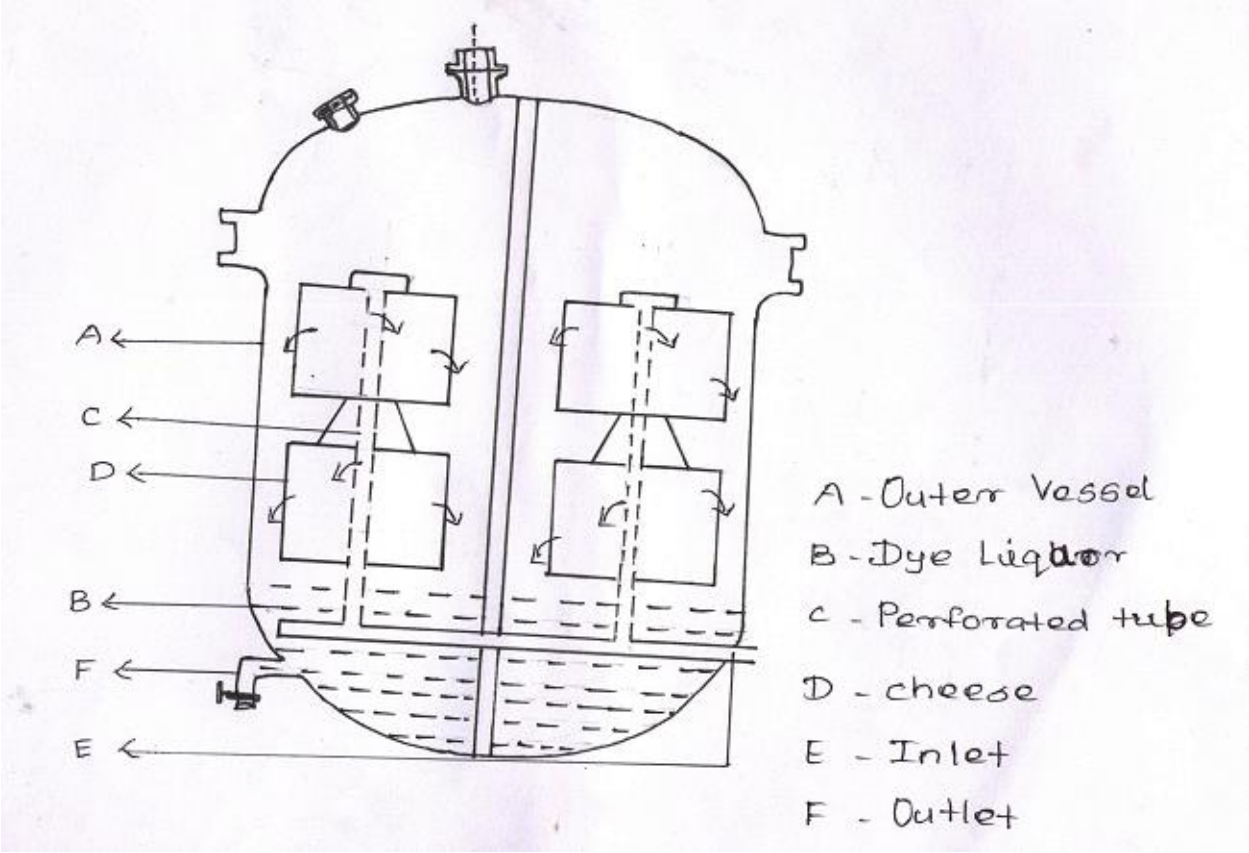


Fig.3.Cheese dyeing machine

4.3.Fabric Dyeing Machines

4.3.1. Jigger

This machine also called Jig is most commonly used for dyeing almost all kinds of fabrics in full width. The jigger is a simple machine which consists of a `V' shaped trough fitted with the draw rollers along each side of the machine. The cloth to the dyed is wound on one of the rollers called the`` LET-OFF'' roller from which it unwound and passed through the dye liquor in the trough with the help of guide roller and an immersion roller to the other draw roller on which it is wound. The dye liquor is heated by means of an open ended steam pipe. The passage of cloth from one draw roller to the other through the dye liquor is called one end or one turn. The number of ends to be given depends on the depth of shade, absorption capacity of the cloth type of dye stuff used and the time required for one end . If all the dye required for dyeing is added to the jigger at the beginning it results in a defect called tailing.ie continuous decrease in the depth of shade from one end of the batch to the other. This is eliminated by adding only half the amount of the dye initially and adding the rest at the end of the first end and before starting the second end. During the dyeing , a rubber roller is kept pressed against the roller on which the cloth is being wound .So that the dye solution can penetrate into the fabric.

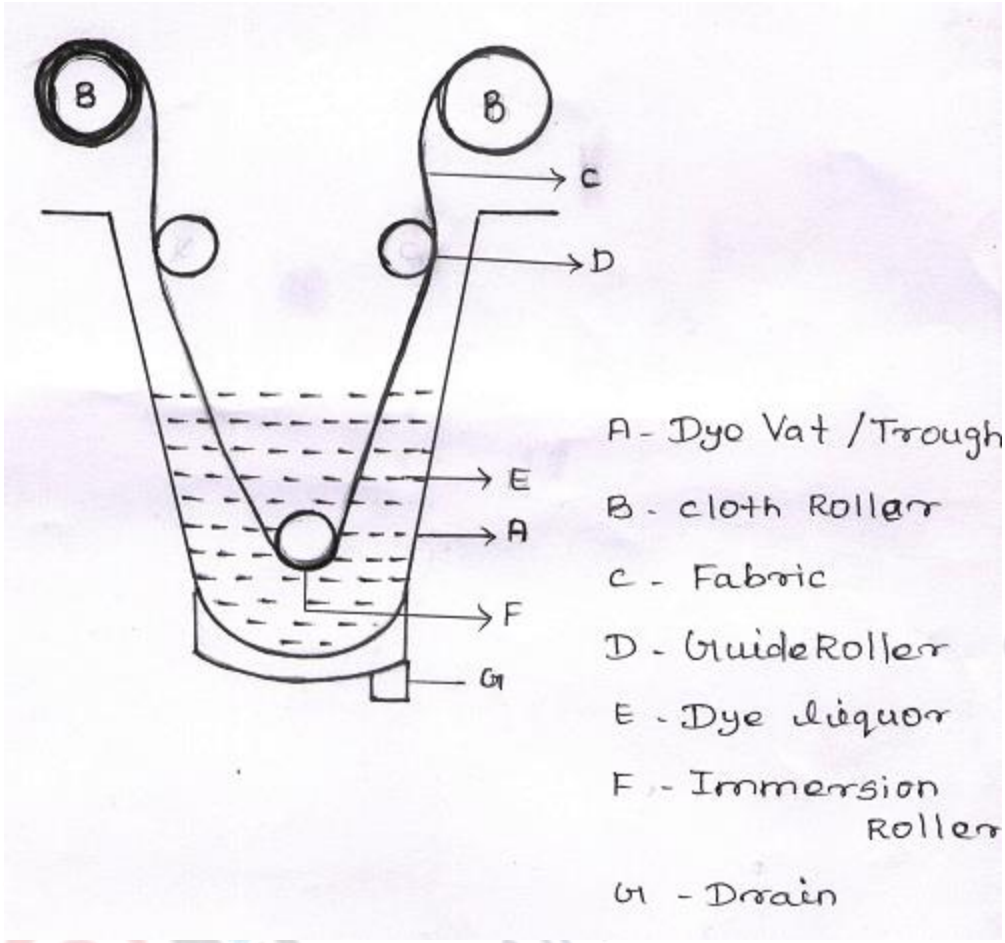


Fig.4.Jigger dyeing machine

Disadvantage is it is a batch wise process and hence only small lot of cloth can be dyed at a time. During dyeing, the fabric is pulled from one roller to the other excerting considerable lengthwise tension which is injurious to delicate fabrics, which have low tensile strength. In the case of heavy fabrics like canvas or twills only surface dyeing of the material takes place because of the difficulties of penetration of dye liquor.

4.3.2.Winch Dyeing machine

During the dyeing of fabrics in a jigger or a padding mangle the fabric is subjected to considerable amount of tension. This is undesirable in the case of delicate fabrics like viscose

rayon, woolen and knitted fabrics. A winch dyeing machine is very suitable for this purpose. In this machine a minimum of tension is exerted on the cloth being dyed.

A dye winch consists of a power driven elliptical reel called winch mounted on a tank, it has a perforated partition near the front which divides it into a small and a big compartment. The small compartment at the front of the machine is provided with a perforated steam pipe, water inlet and outlet arrangements. The addition of the dye and dyeing auxillary is also made in this compartment from where they travel to the other, through the perforated partition. A guide roller is also provided for the movement of the cloth .

In using winch one end of the cloth to be dyed is passed through the guide roller and over the winch. The ends are sewn to make a long continuous loop . The fabric is then run into the dye solution by the action of the rotating winch. During dyeing, the fabric is plaited down the slanting side of the tank in the dye solution at the rear side of the machine, until it is drawn out again by the winch. The movement of the cloth agitates the dye solution. The liquor ratio is much higher. Hence water and heating costs are also high.

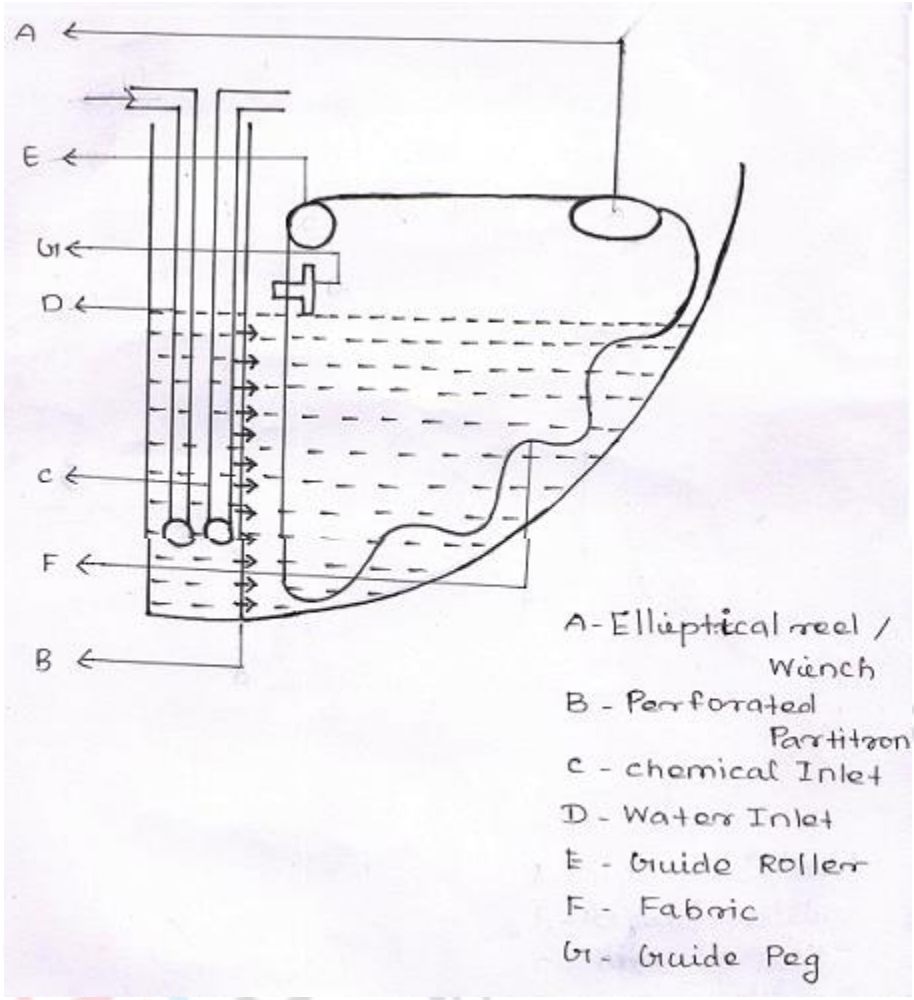


Fig.5. Winch dyeing machine

4.3.3. Padding Mangle

Dyeing on jigger or winch is a batch wise process, only small lot can be dyed. For huge quantities padding mangle is used. Material: liquor ratio is lowest so there is saving in consumption of water steam and chemicals

The basic padding operation consists of passing the fabric in open width through a small trough consisting the processing solution and then removing the excess solution by passing between positively driven squeeze rollers, which constitute the padding mangle.

A simple padding mangle consists of two squeezing bowls the upper one of iron and covered with rubber and the lower one of brass or ebonite arranged over a shallow trough provided with two or more freely rotating guide rollers. The pressure on the bowls is obtained by compound levers and weights. The cloth enters the trough containing the dye solution, after passing through the dye solution it is uniformly squeezed between the bowls and finally is batched (wound on a roller). The contact between the squeeze rollers is known as the nip of the mangle. Since the fabric dips in the trough and is then fed into the nip it is known as one-dip-one-nip operation. In order to get consistent results. The liquor level in trough should be maintained by continuously feeding the liquor at the rate at which the fabric takes up the liquor. If the level drops, the further take up decreases resulting in gradual lightening of the final shade. This defect is known as tailing effect. Thus the level of the liquor in the trough should be maintained till the last part of fabric leaves the padding mangle.

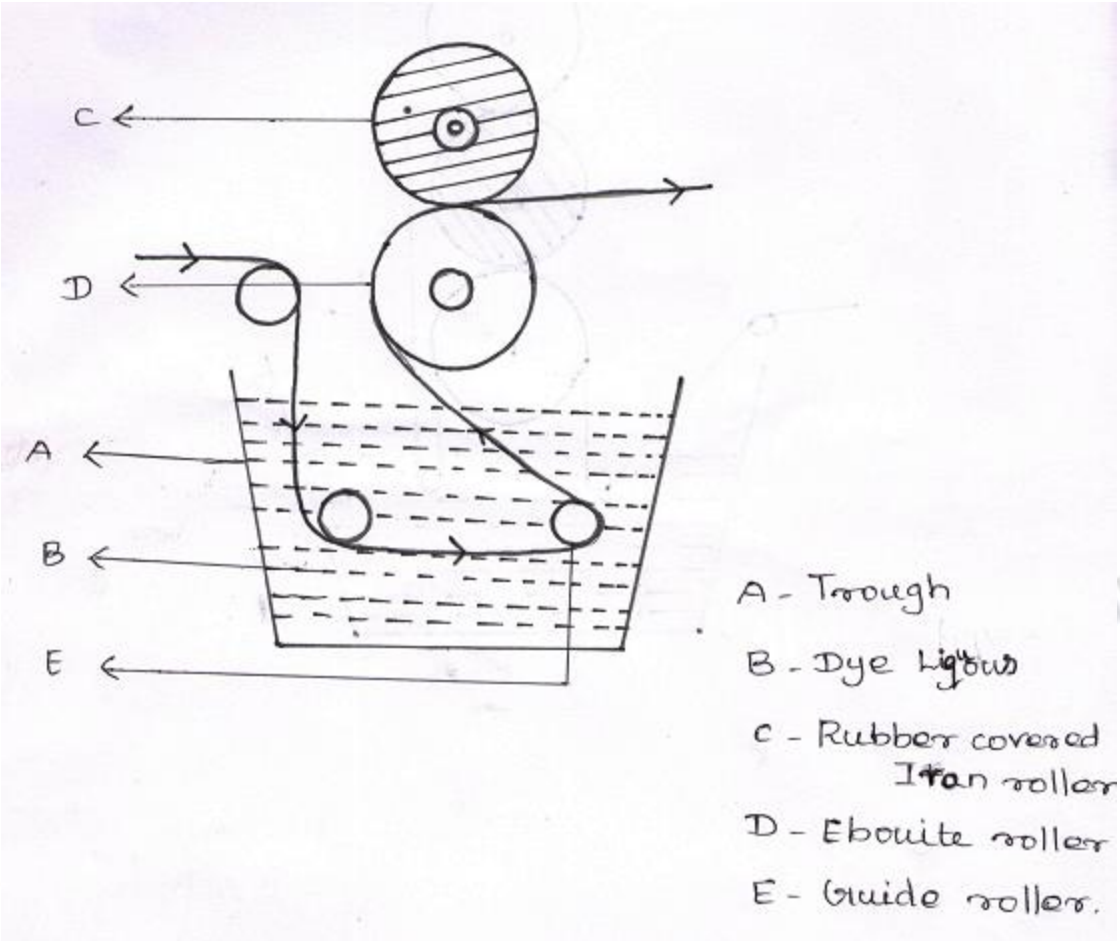


Fig 6. Two bowl padding mangle

In order to increase the penetration of the solution into the fabric, a three bowl padding mangle with two-dip-two nip operation is normally used instead of two bowl padding mangle with one-dip one nip operation. In this case the soft roller is placed between the two hard rollers. The pressure in this padding mangle is applied by hydraulic or pneumatic systems, which enable heavier and more uniform pressure and a more exact control to be obtained than by the lever and weight system one advantage of the three bowl padding mangle over the two bowl machine is that it allows two immersions in the dye liquor and double squeeze so that a better penetration of the liquor into the fabric is possible particularly when azoic or vat dyes are dyed.

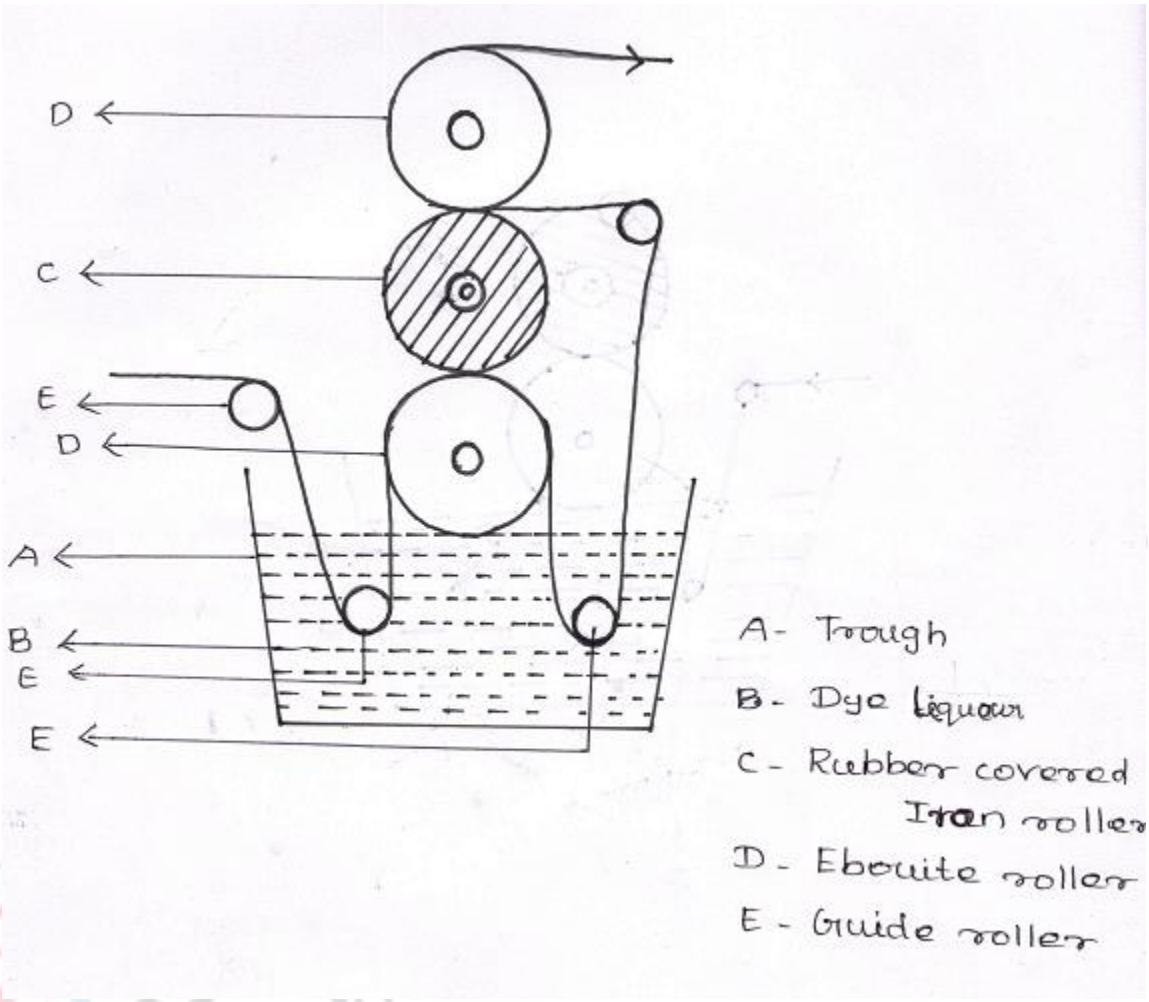


Fig 7. Three bowl padding mangle

4.3.4. High Temperature Beam Dyeing Machine

The hydrophobic synthetic fibers such as terylene necessitate dyeing at temperatures above 100°C. In this machine high temperature and high pressure can be achieved. The machine consists of an autoclave containing the fabric beam through which the dye liquor is circulated by a pump after it has passed through a heat exchanger. The autoclave is completely filled with dye liquor which flows through a cooler and is pumped back into the autoclave by means of injection pump and thereby increasing the pressure inside the autoclave.This machine is useful for dyeing

knitted and woven fabric which is wound on a perforated beam and the dye liquor is circulated alternatively inwards and outwards while the beam is positioned horizontally or vertically within a closed vessel (auto clave) capable of withstanding high pressure to secure high temperature dyeing. The width of the perforated part of the beam can be adjusted for fabrics of different widths. Above 100°C the fibers swell to a greater extent, the molecules of fiber gain energy move about vigorously so that spaces between enlarge and dye molecules which are also energetic enter these spaces and penetrate the fiber.

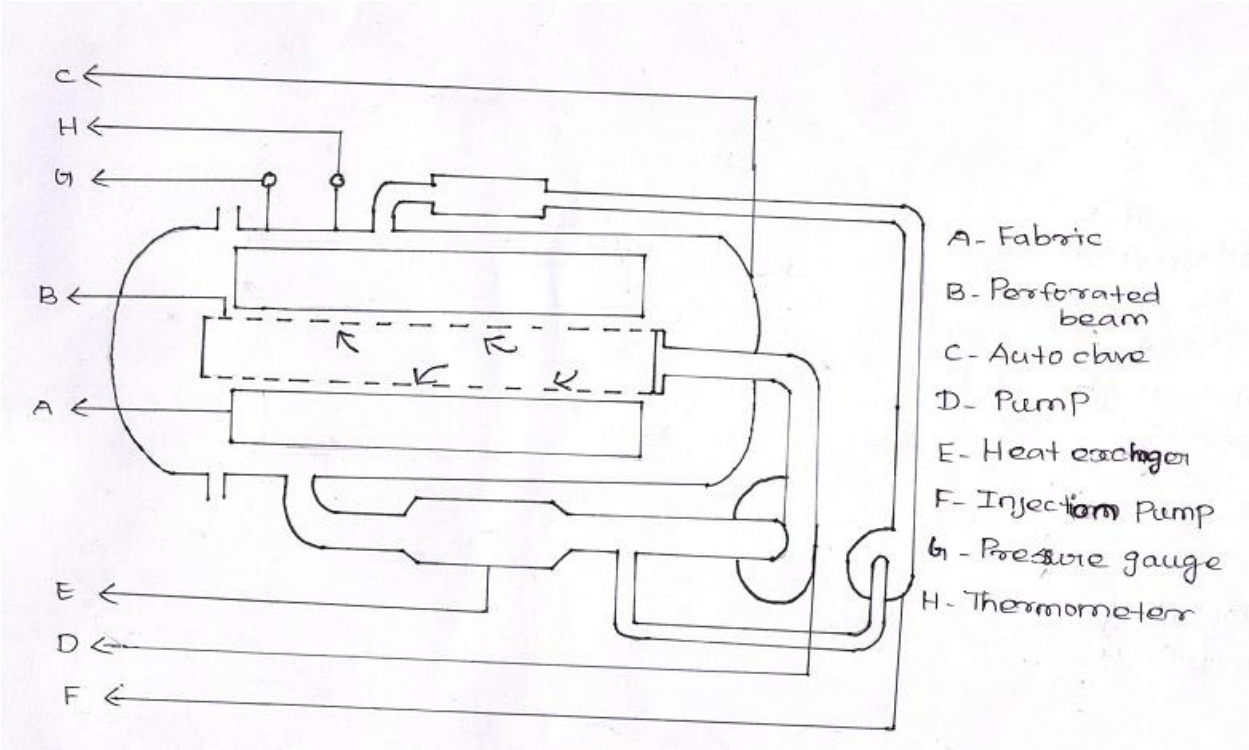


Fig 8 High temperature beam dyeing machine

4.3.5.Jet Dyeing Machine

Is unique in that it has no moving parts, the cloth in rope form is introduced into a unidirectional liquid steam enclosed in a pipe. Liquor is pumped through a specially designed venture jet imparting a driving force which moves the fabric in a totally enclosed tubular chamber . The two fabric ends are sewn together to form a continuous loop. It is becoming very popular for dyeing

knit goods due to the absence of reel or drives. It avoids wear and tear on material so is suitable for delicate fabrics. Gaston county jet dyeing machine is a pressure withstanding cylindrical vessel with up to six separate tubular chambers arranged side by side which are semicircular in shape each containing one rope of fabric. The lifting roller is covered with an elastomer.

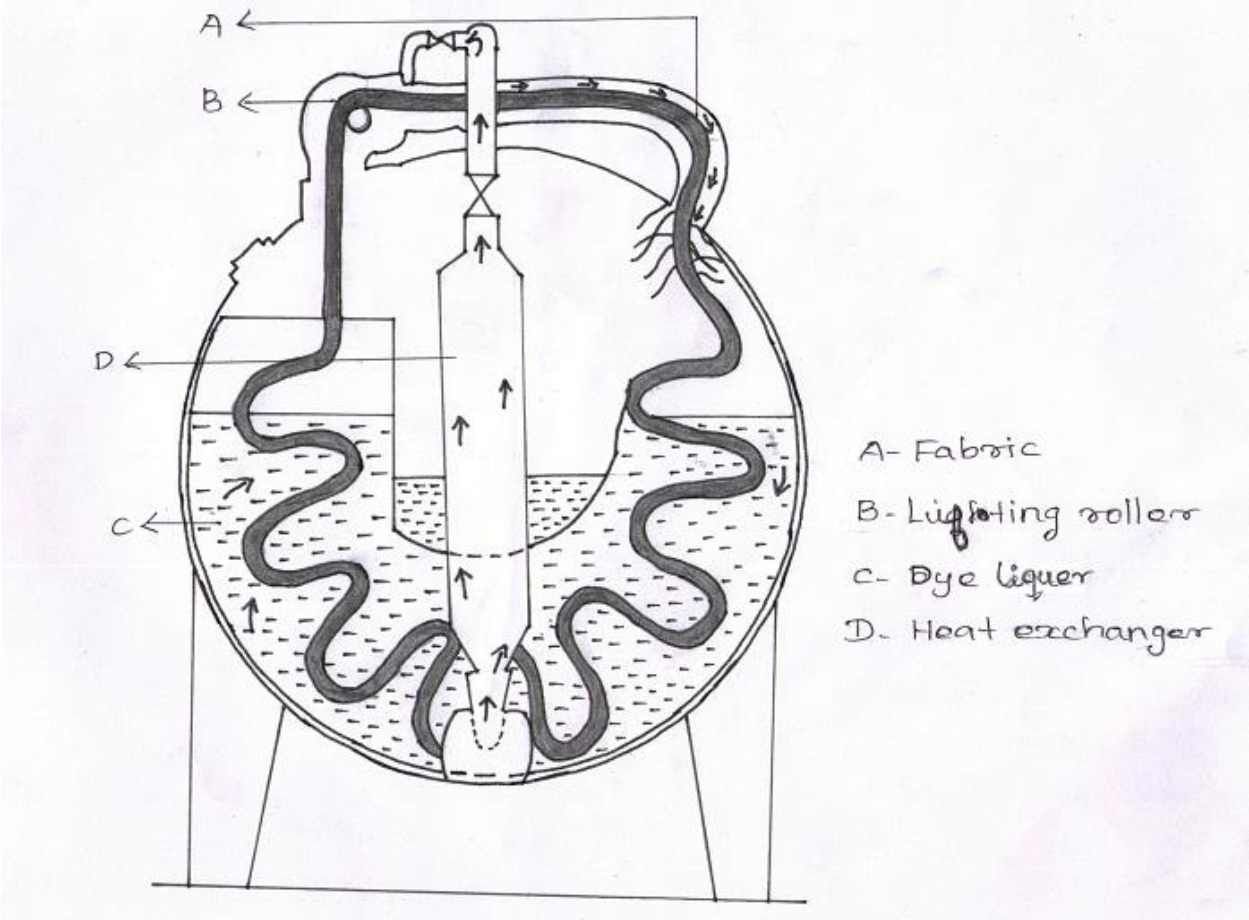


Fig 9 Jet dyeing machine

4.4.Garment Dyeing Machines

4.4.1.Rotating Drum Machine

Silk hosiery is frequently dyed in a rotating drum type of machine which consists of an inner perforated drum with doors. The drum is divided into four equally large compartments.

These compartments are loaded and closed individually. The goods are packed into the drum , the surface of which, for silk stockings, must be polished to the highest degree of smoothness. The least roughness or slightest scratch on the metal causes damaged goods through plucked threads. There is an outer case forming a vessel in which the perforated drum rotates. A reversing mechanism causes the drum to make a certain number of rotations in one direction and an equal number in the other.

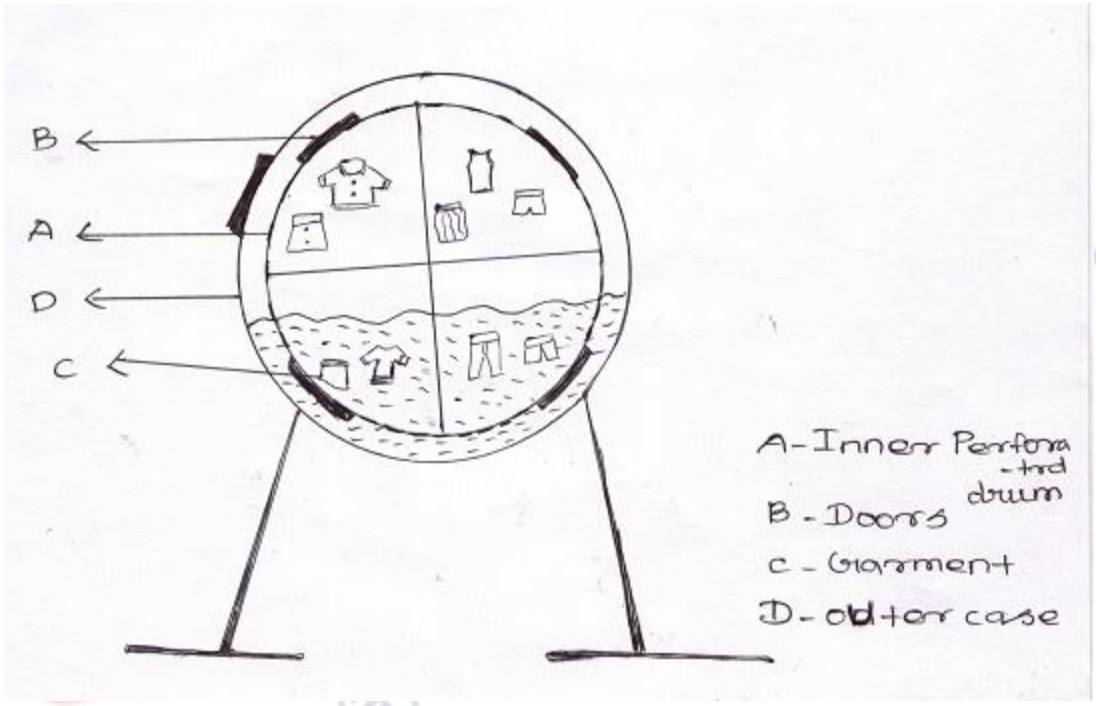


Fig 10-Rotating drum type machine

4.4.2.Toroid Machine

A more recent development is the Toroid machine for dyeing garments under pressurized conditions at temperatures up to 140 ˚C. This is especially useful for dyeing garments containing polyester fibers. The pump circulates the dye liquor in at the bottom and it impinges upon a spreader plate which deflects the flow round the sides of the cylindrical outer vessel. It then flows over the top of the annular cage. Containing the goods, from which the

pump withdraws the liquor through a central perforated pipe. A swirling action is imparted to the dyebath which keeps the goods in constant movement.

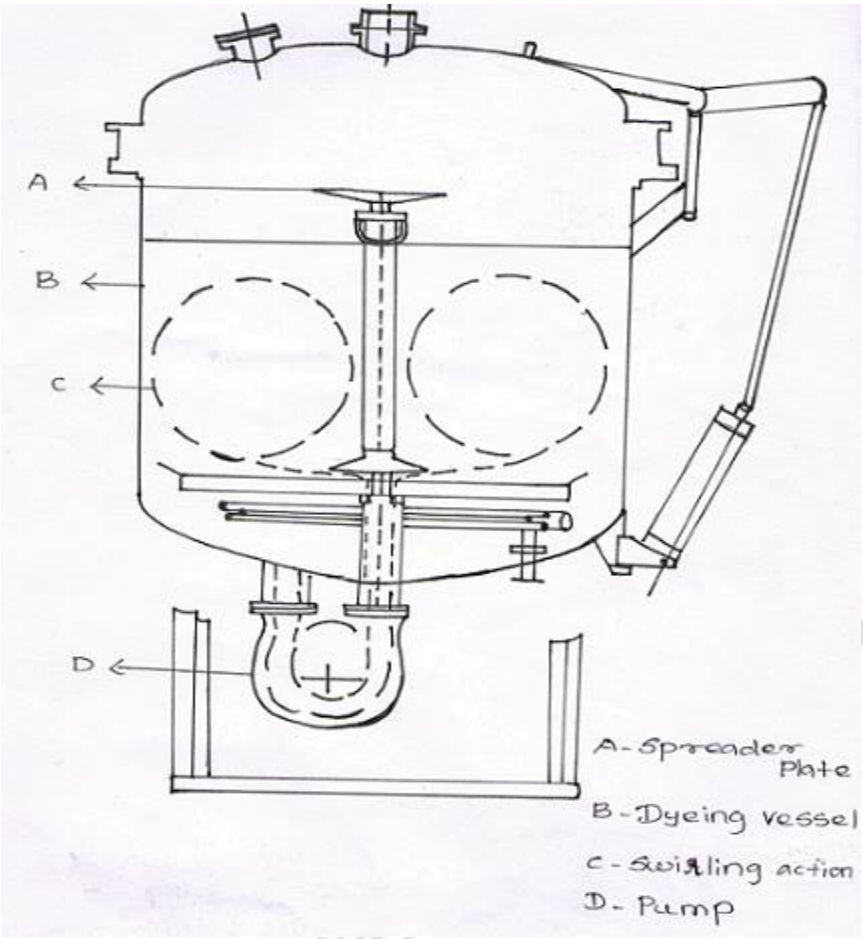


Fig.11. Toroid machine

5. Conclusion

Dyeing can be done in the form of fibres, yarn, fabric or garments. The most economical is to dye at the later stage in the manufacturing sequence. For special effects however it can be dyed at an earlier stage. There are various methods of dyeing , the selection of the method or equipment is based on factors such as dye , fabric characteristics, cost, and the intended end use.