Silk Reeling

The cocoon of *B. mori* is made up of a single long silk thread held together by the cementing sericin along with trace amounts of ash and colouring matter. The process of unwinding the single long silk fibroin by dissolving the sericin and other materials is called **reeling**. A number of preliminary steps have to be followed prior to reeling. These include stifling, drying and storing, cooking and boiling, deflossing and riddling. After reeling, the reeled silk is re-reeled, twisted, thrown and finished before being made into skeins, books and bales for marketing purposes.

19.1 Stifling

Stifling is the first process taken up as soon as the cocoons are purchased/harvested, with the object of killing the pupae inside without breaking the silk filament in the cocoon shell. If stifling is delayed, the pupa inside metamorphoses and emerges by breaking open the cocoon and renders it unreelable. The three methods of stifling are - sun-drying, steam-stifling and hot-air-conditioning.

19.1.1 Sun-drying

In this method, the cocoons are exposed to the scorching action of direct sunlight till the pupa inside is killed and dried. This requires a prolonged exposure of freshly harvested cocoons to bright sun light. Sun-dried cocoons are very light and produce a rattling sound on shaking.

Advantages : The chief merit of stifling by sun-drying is that it is

easy and cheap, and the dried cocoons can be stored for any length of time. Reeling can be done immediately also.

Disadvantages : The main disadvantage is that sunlight of sufficient intensity and duration may not be available continuously in all seasons and in all areas. Further, prolonged exposre to sunlight adversely affects the quality of silk and increases the proportion of silk waste during reeling. The process is cumbersome, requiring more labour and space. The shell hardens during sun-drying, affecting the reelability.

It is still followed in many places in India where facilities for other methods of stifling are not available. It is still followed traditionally in Jammu & Kashmir and West Bengal.

19.1.2 STEAM-STIFLING

In this method, hot and wet steam is used. Depending upon the number of cocoons, basket steaming, barrel steaming or chamber steaming is used

a) Basket Steaming : This method is used for small amounts of cocoons. About 10–15 kg of cocoons are loosely filled in a bamboo basket loosely woven at the bottom. The mouth of the basket is closed with a tightly stretched thick cloth tied to the sides of the basket. The basket is placed over boiling water in a vessel. The steam penetrates through the basket and stifles the cocoons. Heating is stopped when dense smoke starts coming out of the sides of the basket with the characteristic smell of the stifled cocoons. Stifling takes approximately half an hour. The cocoons are removed and tested to ensure that stifling has been completed. Properly stifled cocoons feel hot, damp, soft and slimy to touch, and yield even under slight pressure between the fingers. The pupae obtained by cutting open the stifled cocoons do not wriggle when kept on the open palm.

This is practised in charkha and cottage basin establishments. The stifled cocoons have to be dried in air.

b) Barrel Steaming : This method, though adopted for small and moderate amounts of cocoon, is superior to basket stifling, as it takes less time and ensures more uniform steaming, being done

under closed conditions. A barrel is used in addition to the basket. A metal barrel with a tight-fitting lid is used for steam production. It has an elevated platform at the bottom. Water is filled to two-thirds the height of the platform and heated from an oven below. When the barrel is filled with steam, the basket holding 10–15 kg of cocoons is lowered into the barrel, which is then closed with the lid. The cocoons are stifled in 10–15 minutes, as pressure builds up inside the barrel.

c) Chamber Steaming : This method is used in large filature units where enormous amounts of cocoons have to be stifled. Stifling is done in huge steam chambers supplied with steam from a main boiler unit by perforated steam pipes. Steam supply to the chamber is regulated by valves on the pipes. The chambers are provided with either permanently fixed or portable cocoon shelves. In the first type, trays containing fresh cocoons are placed on the shelves before opening the steam valves. Stifling is over in 15–20 minutes. The stifled cocoons are removed and a fresh batch is loaded on the shelves. In the second type, less time is taken for loading and unloading. When one portable shelf-load is being stifled, another one can be loaded outside and put in when the first shelf is taken out after steaming. The operation is, thus, more continuous.

Precautions : Over- and under- steaming must be avoided. Uniform steaming of the coccons must be ensured. Conditions making for fungus growth must be avoided.

Advantages of steam-stifling : The cocoons are stifled more uniformly and quickly than in sun-drying. Stifling can be done in all seasons. Large quantities of cocoons can be stifled.

Disadvantages of steam-stifling : Unlike sun-drying, steam-stifling only kills the pupa inside and does not dry it. The cocoons are fragile because of the moisture and cannot be stored for long periods. The cocoons cannot be reeled immediately, as the sericin will be wet and the fibroin comes out in lumps during reeling. The cocoons have to be dried for at least three days before reeling or storing. This is called **seasoning.** If they are not dried or seasoned properly, the wet pupa starts decomposing and the fluid oozing out spoils and stains the cocoons nearby. These cocoons

are called **"melted"** cocoons. Fungus growth easily occurs on wet cocoons kept in poorly ventilated rooms. Improperly seasoned cocoons increase silk wastage. During seasoning, steam-stifled cocoons have to be spread in thin layers and repeatedly turned over, to ensure uniform drying and to prevent moulds from developing. This requires extra space and more labour.

19.1.3 Hot-Air Stifling

In order to overcome the main disadvantages in steam-stifling, modern filatures adopt the method of stifling and drying together by hot-air conditioning. In this method, fresh cocoons are dried by means of hot air. Hot-air stifling is suitable for good quality cocoons such as bivoltines. The stifled cocoons can be stored for longer periods.

The main parts of the conditioning unit are: (1) a chamber for the cocoons to be conditioned, (2) a heating element for heating the air and 3) an air-blower for blowing or circulating the heated air into the conditioning chamber. There are two principal types of hot-air stifling - the Italian and the Japanese. In the Italian type, the cocoons are initially subjected to a low temperature (about 50°C) which is increased gradually to about 90°C. The conditioning chamber is divided into five parts by sliding wire-mesh partitions, each maintained at a different level of temperature. In the topmost part, the fresh cocoons are conditioned with hot air at 50°C. Then they are transferred in turn to the second, the third and the fourth to be conditioned at 70°, 75–80° and 80–90° C respectively. The fourth is the unloading chamber. The fifth chamber is separated from the fourth by a fixed partition and is connected to the heating and blower assemblies. The cocoons are retained in each chamber for about three hours, the entire process taking about 12 hours.

In two of the Italian types installed in India, Pelligrano open and closed, the units have a batch type of mechanism for transfer of the cocoons which is done by operating the sliding wire meshes. In the Tamburo-Girato type, also Italian, the chambers themselves are rotated by a cog-wheel mechanism.

In the Japanese type of conditioning units, however, the cocoons are first subjected to a very high temperature of about

95°C for a short period for stifling and then dried in progressively lower temperatures coming down to 50–55°C. The conditioning units also have a conveyor belt mechanism which enables continuous transfer of cocoons from one chamber to the next.

Advantages of hot-air conditioning : Conditioning by hot air completely dries the cocoon so that its weight becomes reduced to one-third the original weight. This method is suitable for any quantity of cocoons - small, moderate or large. When extremely large amounts of cocoons have to be stifled, they can be passed through the chambers quickly, so that they are stifled and are partially conditioned. They can be completely conditioned by passing them through the chambers once again. The operation is continuous so that there is no time-lag between the discharge and recharge of the cocoons. The entire process is electrically operated and hence the cost of labour is less.

Disadvantages : The equipment is costly and is suitable only for very large establishments. Repair, maintenance as well as operation require skilled labour with technical knowledge. This is suitable only for very good quality and uniform-sized cocoons. Cocoons of different sizes, as is common in Indian markets, will be conditioned to different degrees, and some may even become charred.

19.1.4 Other Methods of Stifling

Other methods that have been tried include stifling the cocoons by (i) infra-red rays, (ii) one-step drying cellar method, (iii) cold air, (iv) radio wave and (v) poisonous gases. None of these methods are commercially adopted.

19.2 Storage of Cocoons

The seasoned or conditioned cocoons can be reeled immediately, but generally require to be stored for varying periods in reeling units. Cocoons can be stored for one month when steam-stifled, and for four to six months, when hot-air-dried. During storage, they may be damaged by either the beetle (*Dermestes lardarius*) or by fungal growth. The larvae and adult beetles are attracted by the smell of

the stifled cocoons and they eat the pupa after cutting open the cocoons. Fungal growth occurs if the cocoons are not dried properly or if the store rooms are wet and humid. The cocoons are subject to attack by rats, ants and other insects. The following precautions are to be taken against these pests.

1) Steam-stifled and hot-air stifled cocoons should be stored separately.
2) The cocoons must be dried completely.
3) They must be stored in rooms with good ventilation, so that the humidity inside is maintained below 70% R.H. Ventilation also aids in removing traces of fumigants used in disinfecting the rooms.
4) The cocoons must be inspected and turned over frequently, so that they have good aeration. They must be spread in thin layers, if steam-stifled.
5) Any stained or mould-attacked cocoon must be carefully removed.
6) Cocoon wastes and reeling wastes must not be stored in the same room or even in the same neighbourhood.
7) Hot air at 60–70°C should be passed into the storage room to kill insects.
8) Storage room should be protected from direct sunlight but there should have sufficient aeration.

19.3 Sorting of Cocoons

After stifling, the cocoons are sorted for a second time, prior to reeling, so that cocoons of uniform size are reeled at a time. Workers who do this are called **sorters**. A specified quantity of cocoons is assigned to each to sort in a specified time. The defective cocoons generally encountered at this stage are: (a) "double" cocoons, (b) crushed and stained cocoons, (c) flimsy cocoons, (d) malformed cocoons, (e) fluffy or flossy cocoons and (f) cocoons pierced by Uzi fly maggots or damaged by dermestid beetles.

For sorting, the stifled cocoons are spread thinly on tables. The sorters pick out the defective cocoons, "double" cocoons and cocoons of different sizes and put them in separate containers. In this method, cocoons are examined only superficially. For

detecting internal defects in the cocoon, the Japanese spread them on a glass plate illuminated with fluorescent light from below. In smaller units, instead of electric bulbs, mirrors reflecting light from doors and windows are used to illuminate the cocoons.

19.4 Deflossing

Floss is the unreelable tangled mass of silk found on the outside of the cocoons. To find out the true reeling end of the cocoon and proceed with continuous reeling, the floss layer has to be removed. This process is called **deflossing** and is done just before reeling, as floss forms a protective covering to the reelable compact shell.

In India, with predominantly multivoltine cocoons, deflossing is done individually, by peeling off the floss layer with hand. Though removing of floss manually is a time-consuming and laborious process, it has the advantage that the required length of floss alone will be removed from each cocoon. In charkha and cottage basin reeling, deflossing is done by the reeler himself, who may do it with his hands or with simple devices, like sticks. In Japan, with predominantly uni/bivoltine cocoons, simple appliances like brushes, hand- or machine-operated, are used for deflossing. These devices are not suitable for Indian cocoons, which are too flossy.

19.7 Cocoon Cooking

The silk baves are gummed together by the sericin in the cocoons. In order to unwind the bave, the sericin has to be dissolved. This is done by putting the cocoons in hot water and this process is called **boiling or cooking.** The sericin content ranges from 25 to 30% of the shell and 7 to 8% of it is dissolved during cooking. Boiling softens and swells the sericin before dissolving it. Care should be taken to see that the sericin is not completely dissolved, as it is the sericin that cements together the baves from more than one cocoon so that silk thread of the desired denier is reeled. The water used should not be too hard (not more than 80–90 ppm). The pH should be between 6.8 and 7.4. CSTRI has developed softening agents to bring down the hardness and pH to the desired level. The higher the alkalinity of the water used and the longer the boiling time, the more the amount of sericin dissolved and this may affect the cohesion and lustre of the silk reeled.

The method of boiling differs according to whether the floating system (top-reeling) or the sunken system is adopted for reeling. The sericin in the outer layers is more soluble than that in the inner layers.

19.7.1 Boiling for Top Reeling

In the top reeling system, during cocoon boiling, only the outer shell is wetted and the cocoons float in the water in the reeling basin. The cooked cocoons are reeled in reeling basins having a water temperature of 40–45°C which is too hot for the reeler's hand and decreases his efficiency. Large quantities of water are required to supply water and steam to the cooking and reeling basins. Installation of water and steam pipes as well as production of steam is costly. Due to the condensation of water vapour, humidity in the reeling room increases leading to **mill dampness.** As the reeler has to do the brushing as well as reeling.

his efficiency decreases. As separate persons are required for cooking and reeling, labour cost also increases. Boiling is done either by the open pan system or three-pan system.

a) Open Pan System: The boiling is done in an open earthenware or copper vessel, in which water is boiled directly over the fire (Fig. 19.1). Cocoons are put into boiling water and kept immersed in it by a wooden ladle till they are cooked, i.e., become dull, translucent and soapy to touch. The filament comes off easily only from the cooked cocoons. The open pan is sometimes provided with an automatic brush which serves to keep the cocoons inside the water as well as to brush the floss of the cocoons. This system is adopted mainly in charkha reeling where only limited amounts of cocoons are reeled at a time and the reeler himself can supervise and ensure that cooking is done to the correct degree. It is easy, cheap and requires less labour. The major disadvantages are– all the layers of the cocoon are not cooked to the same degree, i.e., when the outer layers are completely cooked, the inner layers are not cooked and when the inner layers are cooked, outer layers are overcooked; wastage of cocoons due to overcooking and undercooking is common. The pan can hold only a small amount of cocoons and hence cooking is a time-consuming process. The water becomes dirty quickly and has to be replaced periodically, which is uneconomical as well as time-consuming.

Three Pan System: This cooking system, commonly followed in cottage basin units (Fig 19.2), is designed to overcome the

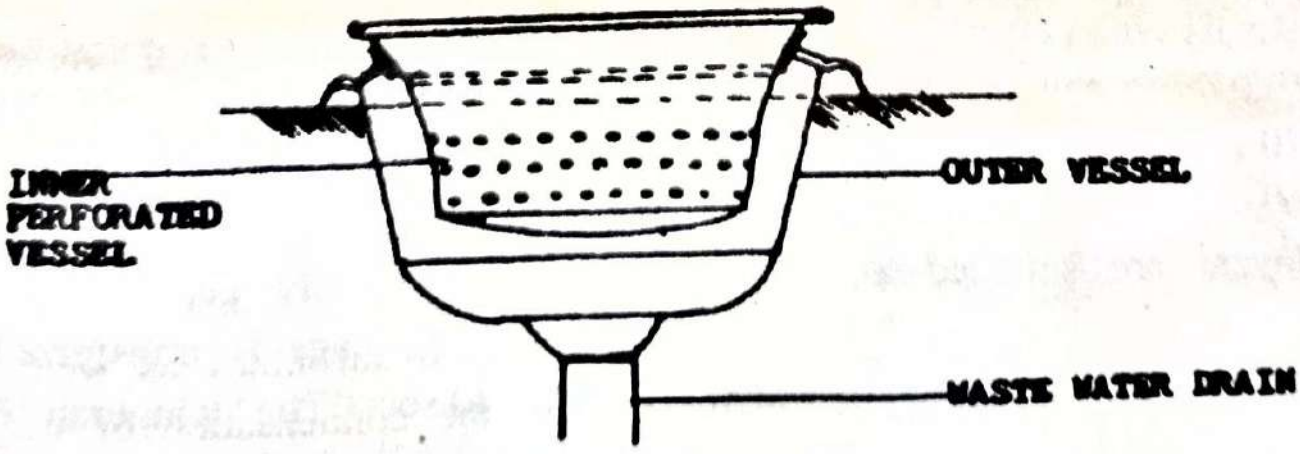

Fig. 19.1 Open Pan Cooking Unit

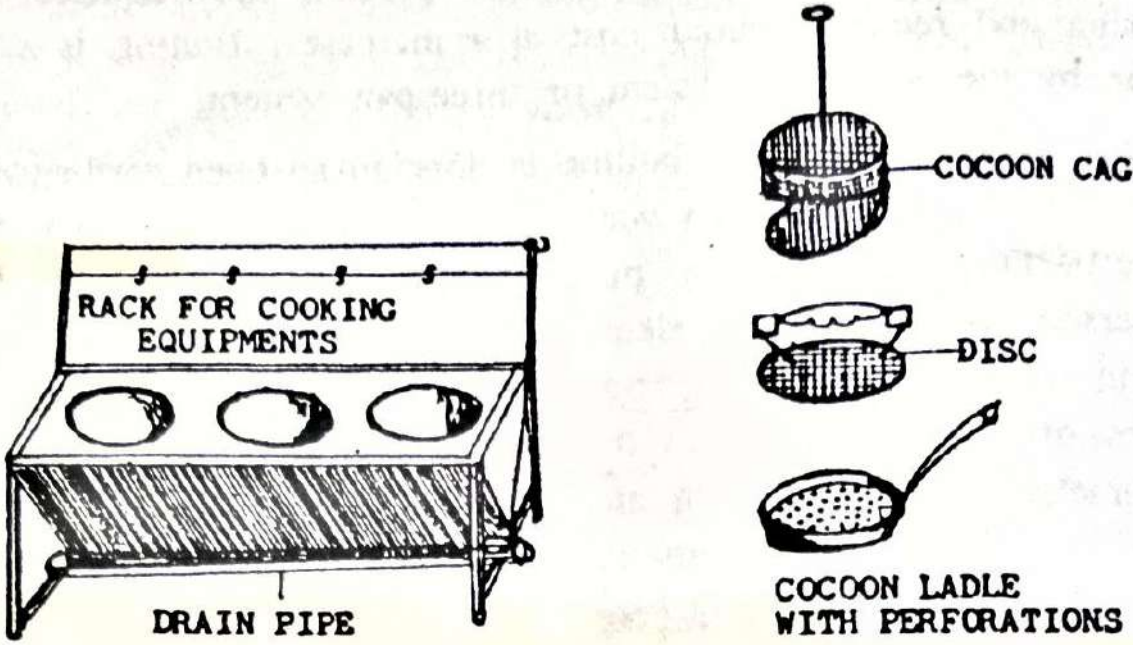

Fig. 19.2 Three Pan Cooking Units and Accesories

defects of the open pan system. It can handle moderately large amounts of cocoon and the boiling process can be continuous. It is suitable for cooking compact-shelled cocoons like bivoltines. The main parts of this cooking unit are: 1) a platform or a table, 2) three basins or vessels of copper of moderately large size fixed permanently in a row on the platform, 3) long-handled brass wire cage for holding the cocoons, 4) long-handled perforated ladles, 5) an open shelf for holding the accessories, 6) cocoon receiving trays, 7) cocoon transporting trolleys, 8) steam and water connections to the cooking basins.

Two methods are followed in this system. In the first method, the cocoons are initially subjected to cooking at a high temperature (98°C) in the first pan, to a lower temperature (65°C) in the second pan and finally to a high temperature (97°C) in the third pan. The wire mesh cage is filled with 60–70 kg of cocoons and immersed into the first chamber for 60 sec. Due to the action of the hot water, the outer cocoon layers are softened and air in the cocoon cavity gets heated, expands and is expelled. Next the wire mesh cage is transferred to the next chamber and held for 30–40 sec. The temperature of the water in this chamber being lower, the air in the cocoon cavity gets condensed and water from the basin is sucked into

the cocoon, completely soaking the sericin and loosening the cocoon layers. Next the cocoons are transferred to the third chamber and kept immersed in its water with the help of the wooden ladle for one to two minutes till the cocoons are cooked. Then they are transferred to a bucket of water at 45°C for 10 min before loading them to cocoon transporting trolleys to be carried to the reeling basins.

In the second system, the cocoons are first cooked at a low temperature (65°C for 60 sec) in the first pan, a higher temperature (98°C for 90 seconds) in the second pan and once again to a low temperature (65°C for 60 seconds) in the third pan. As in the first system, the cooked cocoons are collected in a bucket of water at 45°C and kept for 10 minutes before being taken up for brushing in the reeling basin.

The improvements achieved in this system are: Large amounts of cocoons are cooked in a short time; the reeling quality is improved as water permeates through the layers of cocoon into its cavity and softens the sericin in all layers; as the cocoons are subjected to standardised treatment, cooking is uniform for all the batches; as brushing and cooking are not combined, water does not get fouled too quickly and as cooking basins have water and steam connections, changing of water is easy.

19.7.2 Boiling for Sunken System of Reeling

Cooking for the sunken system of reeling has the following advantages over that for the floating system. All the cocoons and all the layers of each cocoon are uniformly softened. This reduces silk wastage to the minimum. Number of workers required for cooking is very much reduced and this brings down labour costs. Reelability is so much improved that the cocoons are suitable for reeling in multi-end reeling units in which each reeler can reel about 40–50 ends at a time. As reeling is done in lukewarm water, not only the steam consumption but also mill dampness is reduced. Percentage of gum-spots, ribbing and plastering defects are reduced and cohesion property is increased in the reeled raw silk.

In this system of boiling, air in the cocoon cavity is largely replaced by water and the heavy cocoon remains sunken within

the water during the reeling operation. This is actually a modification of the three-pan system in that by subjecting the cocoons alternately to hot and cold water, air in the cavity is made to expand and be expelled first and then contract and condense facilitating the suction of water into the cavity.

(a) Traditional Method : In the old traditional method cocoons are first put in a basin containing water at 83–93°C under cover and heated for sometime. Then boiling is continued after removing the cover for one-third of the total cooking time. A spray of cold water is sprinkled on the hot cocoons for the air inside it to contract and water in the basin to be sucked in. Boiling is again continued for sometime. After cutting off the heat supply, cocoons are douched (sprayed) with cold water once again and then conveyed to reeling basins having a temperature of 40–45°C. This method effectively fills up more than 90% of the cocoon cavity with water. As all the operations are carried out in the same basin, conditions of temperature and pressure are likely to vary. Only a limited amount of cocoons can be cooked at a time.

(b) Conveyer Type Boiling Unit : The defects of the traditional method of boiling for the sunken system of reeling are rectified in the "conveyor cooking machine" and "central cocoon boiling machine" used in modern filature establishments.

The machine consists of a sturdily built long rectangular container firmly held in an iron frame. The container has five or six processing chambers and one open chamber for loading the cocoon. The size and structural design of each chamber is different to suit a particular function. Each is provided with independent water and steam circuits, a thermometer, pressure guages and inspection windows and also with a thermostat and an automatic control device to maintain the desired temperature and steam pressure. There are also overflow pipes for draining and maintaining a steady level of water in the chambers containing water. A conveyer, operated by a pulley, transports the brass cages containing the cocoons from one chamber to the next continuously. Cocoon cooking involves sequential operations of pre-treatment (soaking, steam permeation), steam cooking, post-treatment (adjustment and

post-permeation). The pre-treatment warms the shell evenly, the cooking swells the cocoon and replaces the air in the cocoon cavity with steam and the post-treatment adjusts the swelling of sericin and replaces the steam in the cavity wtih hot water and prevents cocoon collapse.

c) *Circular Type :* The circular cooking unit is hand-operated. Water and steam connections are provided to the unit for cooking. The capacity of the unit is 6 kgs of cocoons. The cocoons are placed in 12 perforated baskets made of stainless steel. The cocoons are alternately dipped in water in the unit maintained at 70°C and exposed to steam above at 85°C. For steaming, the baskets are raised above water and exposed to steam provided from an external source. The sequence is: 1) soaking at 70°C for 30 sec under water, 2) steaming at 85°C for 5 min above water, 3) soaking at 70°C for 30 sec under water, 4) steaming at 100°C for 10 min above water. The cooked cocoons are immersed in water and cooled to 60°C by sprinkling cold water.

19.8 Brushing

After the cocoons are cooked thoroughly, they have to be brushed for removing the floss layer. In the open pan system, brushing is done along with cooking, while in the three-pan system and in the sunken system, it is done separately.

In the Indian charkha reeling units, the floss layer is removed individually from each cocoon by peeling off. A single stick or a prong made of two pieces of sticks or twigs is used to remove the floss from multivoltine cocoons for reeling in country charkha. The stick is introduced within the basin containing cocoons and gently tilted among the cocoons. Sometimes a hand brush similar to a broom, made of strong vegetable fibres (khus-khus or paddy straw) is used. The floss wound round the sticks is lifted and removed and kept aside for cleaning and drying, to be marketed as floss waste. It is called Ekkadi or Dokadi depending upon whether one or two sticks are used for collecting the floss.

In advanced countries, machines are used for this purpose. Italians introduced automatic mechanical brushing for Japanese

and European cocoons. In filatures, even in India, mechanical brushes are used. When the cocoon are boiled in cooking basins, the automatic brushes are brought in touch with the cocoons. The brushes are rotated through an angle of 240°. This rotary movement is repeated 20 to 24 times. The floss comes off along with the reeling ends. The filature floss waste has a higher marketing value than that from other units.

In modern multi-end reeling basins, a modified specially designed mechanical brushing machine provided with a number of small brushes is used.

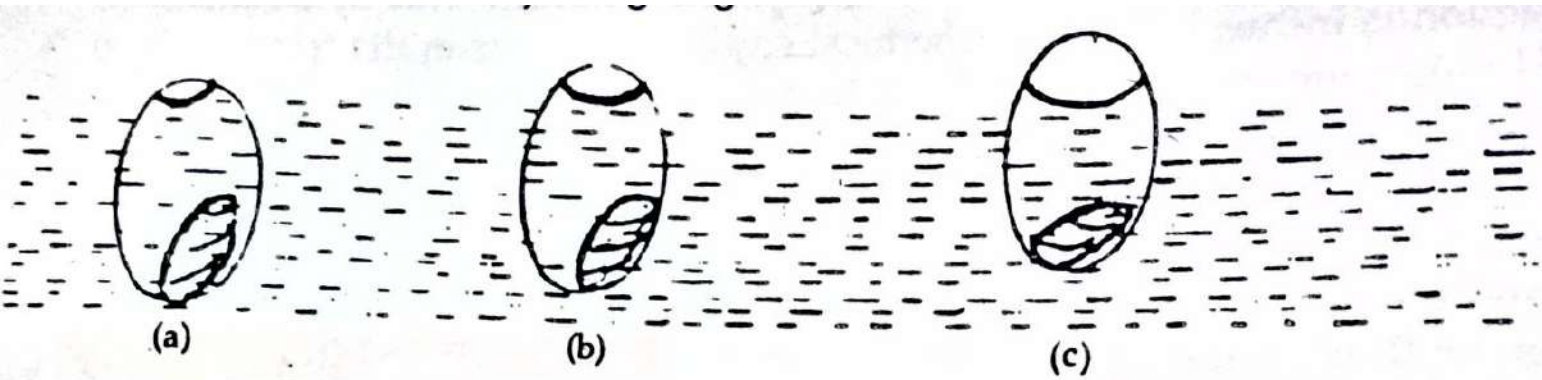

Fig. 4.3. Water permeation level in the Cocoon
(a) Above 97%, (b) Between 95-97%, (c) Below 95%

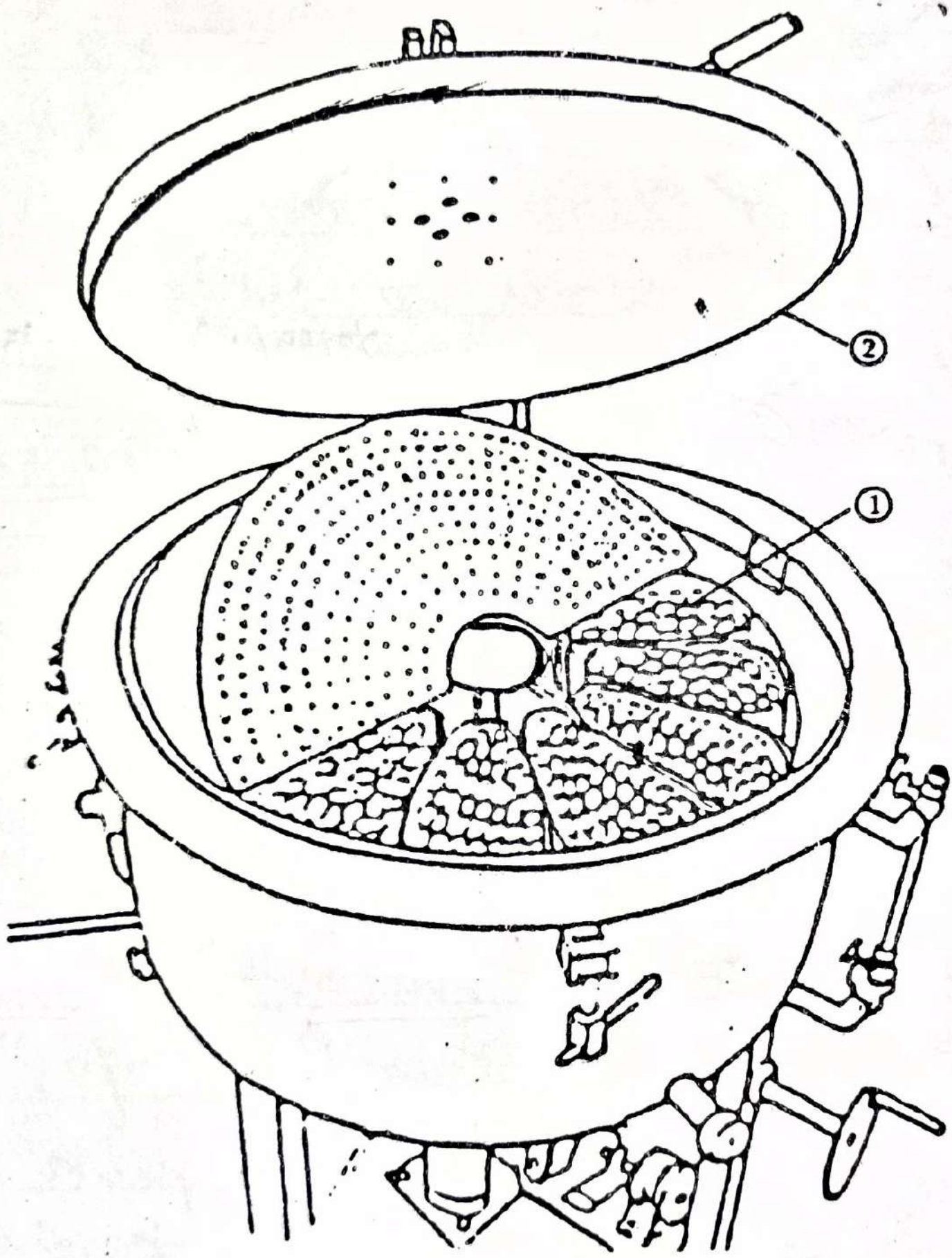

Fig. 4.7 Circular cocoon boiling machine.
1. Cocoon cage, 2. Cylinder lid

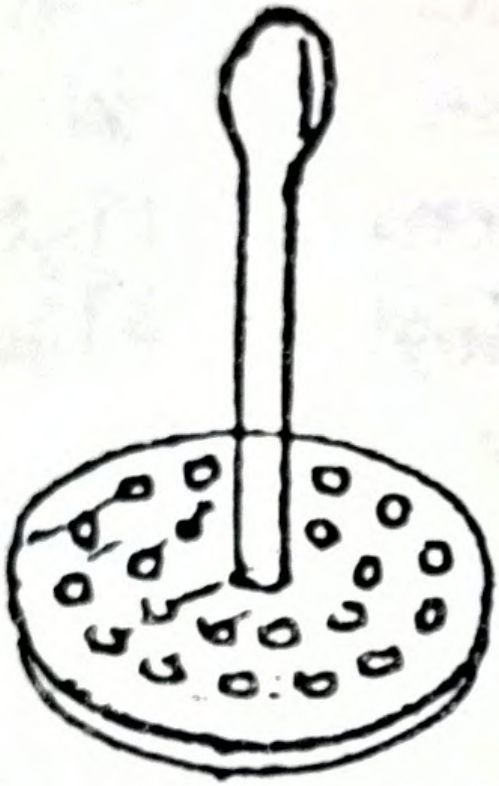

Fig. 4.5 Cocoon depressor plate.

4.6 COCOON BRUSHING

Cocoon brushing is carried out in order to find the correct end of the filament which is embeded in the flossy layer of the cocoon shell. The process of detecting the end of the filament is also termed as *end groping*. Brushing is done by two methods:

(1) Manual
(2) Mechanical

4.6.1 Manual Brushing

This is the most common method adopted in small silk reeling industry having charaka, cottage basin and filature basin. After boiling the cocoons by the conventional pan method, the cocoons are brushed in the same bath, with the help of a long stick of 20-25 cm. (Fig. 4.9). The surface of all the cocoons in the bath is gently touched by moving a stick vigorously in the bath. By this action, the outer floss of the shell layer adhere on to the stick and when the stick is lifted up, the filaments of the cocoons also are lifted. The entangled filaments are cleared by shaking the filaments until a clear single filament from each cocoon is obtained.

After separating the entangled portion from the clear filaments, the cocoons are transfered to the reeling basin/tray. Even though the method is simple it has many disadvantages.

1) The material used for the purpose of detecting the filament end is a hard rigid material and the action is harsh on the softened cocoon.
2) The motion of the stick is vigorous and not uniform.
3) Filament on the cocoon surface could be damaged due to the harsh treatment.
4) Silk waste generated is more.

Fig. 4.9 Manual brushing of cocoons.

4.6.2 Mechanical Brushing

In the units with multiend basin, semiautomatic and automatic reeling machines, the cocoons are boiled in machines, the cooked cocoons are brushed by a machanical device at the reeling machine itself.

Each reeling machine/ reeling tray (in case of multiend reeling machine) is fitted with a brushing device for feeding the brushed cocoon to the reeling ends. The process of brushing, end gathering and clearing the filaments and collecting the cocoon with filament are carried out mechanically.

The simple brushing equipment fitted to the multiend machines consists of a rotary disc, which gets a reciprocal rotary motion from the jettebout driving shaft by gear or by a poly-urethane cord (Fig. 4.10).

The disc is fitted with a handle on the top and three or four small holders to hold paddy straw brushes at the bottom surface. This brushing disc can be lowered into a brushing vessel fixed beside the reeling tray and is fitted with water and steam supply. Cooked cocoons are taken in a pan with perforations in the bottom and which can fit into the water vessel. For brushing the cocoons, water in the brushing vessel is heated to about 85-90°C. Cocoons are taken in the perforated pan and placed in the brushing vessel and the brushing disc is lowered on the cocoons. After a determined number of reciprocal motions the paddy straw picks up the softened filaments on the suface of the cocoon. The disc is lifted and the filaments are separated from the brush, either by mechanical means or manually. The filament ends are cleared and the cocoons are transfered to the reeling tray.

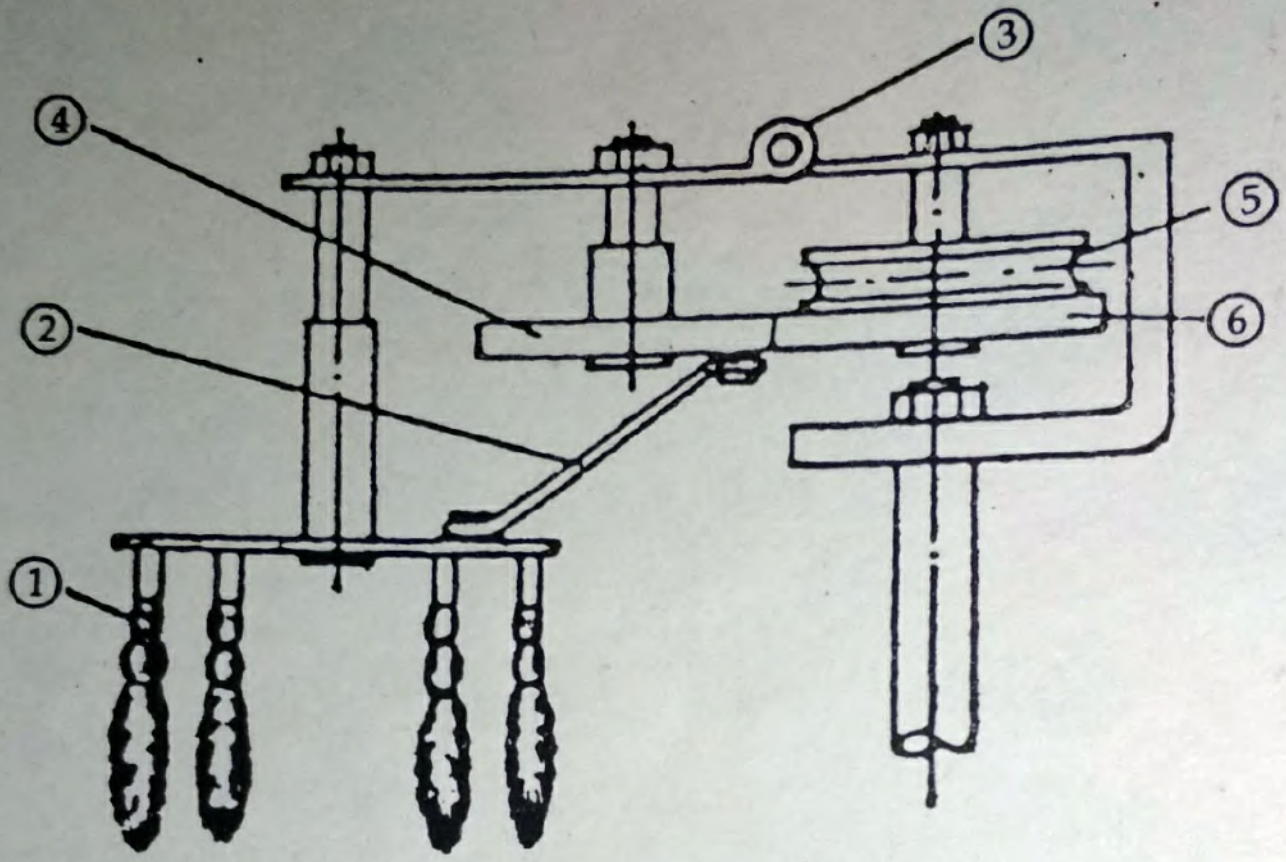

Fig. 4.10 Mechanical brushing of cocoons.
1. Paddy straw brush, 2. Connecting lever, 3. Hinge, 5. & 6. Drive assembly