Indian Journal of History of Science, **18** (2) : 206-219 (1983)

THE TECHNIQUE OF GLASS MAKING IN INDIA (1400-1800 A.D.)

MAMATA CHAUDHURI

The Asiatic Society,
1, Park Street, Calcutta 700 016

(*Received 20 May 1980; after revision 23 October 1981*)

Mediaeval lexicography and medical literature contain innumerable references to glass vessels for daily use and for pharmacy. The glass industry began to flourish in India with the advent of the Moslems. Stratified bangles found at Kolhapur and other centres in the Deccan are noteworthy examples of glass wares of the Bahmani period (1435-1518 A.D.). During the Mughal period, a large variety of glass vessels were manufactured which included *hukkahs*, scent bottles and ewers. Gilt and enamelled glass are known from this period. Glazing of pottery and tiles of this period shows Persian influence. Luxury articles such as mirrors, chandeliers and window panels were constantly in demand at the court, and were imported by the East India Company. In this connection it is to be mentioned that there is little information on record regarding their composition and process of preparation. Here an attention has been given to the technique of the preparation of glass objects, based on the information now available from the local workers of various sites.

From the prehistoric period (by the 2nd millennium B.C.), the people of Mohenjodaro and Harappa through trade contacts with ancient Sumer had learnt to mould and fuse articles of faience and to glaze quartz beads with a frit akin to glass. Excavations at different sites (e.g. Maski, Rupar, etc.) have brought to light glass bangles of chalcolithic age datable to 1st millennium B.C. Mention of glass (*kāca*) also occurs in early Sanskrit and Buddhist literature such as in the *Śatapatha Brāhmaṇa* (1000 B.C.) and *Vinaya Piṭaka*. But the source-materials, on which the information during the period 1400 to 1800 A.D. is mainly based, include literary, archaeological evidence and glass specimens deposited in different Museums.

I

The use of glass as vessels and utensils are found in many medical works, alchemical texts,[1] treatises on jewels,[2] Sanskrit lexicon[3] etc.

The use of spectacles, now prevalent in all civilized nations, is found in a Sanskrit text named the *Vyāsayogi-carita*[4] (a bibliography of Vyāsarāya, the great Madhava pontiff of A.D. 1446-1539) by Somnath Kavi, contemporary of Vyāsarāja.

II

Archaeological excavations give more or less definite information about the knowledge of glass and glass making in ancient and medieval India. It helps to determine the period in which the excavated specimens were fabricated from the position of which the stratum in which they were found. Coins, associated with many excavated specimens of glass wares, also provide another source of dating of the latter. In some cases where specimens were associated with carboneous matter, radio-carbon dating has furnished a very important means for dating them. Varieties of glass specimens (beads, bangles, vessels and miscellaneous objects) are considered here.

Hastinapur

The occupation at Hastinapur,[5] in Mawana Tehsil of Meerut District in U.P. may be divided into five phases. Of these Phase V (11th to 15th century A.D.) is remarkable for opaque and translucent glass bangles of various colours.

Rajghat

The excavation at Rajghat,[6] in the district Varanasi, brought to light six periods of human occupation, ranging in date from *circa* 6th or 5th century B.C.—17th century A.D. Polychrome type of glass bangles were recovered from Phase VI (*c.* 14th to 17th century A.D.).

Patna

Five periods of occupations at Patna[7] ranging in point of time from *circa* 6th century B.C. to 17th century A.D., with a gap of nearly one thousand years between A.D. 600 to A.D. 1600, were revealed. Of these, Period V (A.D. 1600 and later) yielded glass-beads along with terracotta figurines with typical Muslim and Maratha headdress, silver coins of Shah 'Alam' etc.

Kumrahar

Kumrahar,[8] the well-known site of Mauryan pillared Hall at Pataliputra (Patna), reveals six phases beginning from the 2nd century B.C. to 18th century A.D. with diverse glass objects, translucent and opaque.

Antichak

From the second phase (1300-1500 A.D.) at Antichak[9] in the district of Bhagalpur (Bihar), were recovered a few pieces of green glass along with terracotta beads of various shapes, seals, sealings and inscribed sherds etc.

Eran

The stratigraphy of Eran,[10] in the district of Sagar, from bottom to upwards covers four different periods. Of these the IVth phase, extending the 16th to 18th century A.D., is rich in glass bangles.

Sirpur, a glass-making centre

Sirpur,[11] in the Chattisgarh division of Madhya Pradesh, enhanced its glory for the discovery of a glass industry in the end of the Medieval period and the beginning of the Muslim rule. The excavation in the township area near the cluster of monastic buildings revealed a large number of thick potsherds of storage jars (*rañjans*) in which glass was melted or annealed in ancient times. Besides, the existence of large quantities of glass slags and drawn wires suggest that perhaps glass was actually made and worked there. Varieties of bangles seem to be mainly prepared there. For example, extra-ordinary thick rods, nearly 2-3 cms. in thickness and amber and brandy coloured glass were used for bracelets; another variety was thinner in size and used as a base-plate, over which was stuck a rod of dull opaque green-blue glass with various designs. Others, found in large numbers, are both flattish and triangular in section. Besides these, bangles with monochrome variety of very simple technique were also available. Dark leafy green, amber, purple and translucent green were the chief shades of colour employed for the preparation of these bangles and bracelets.

Maheshwar and Navdatoli

The sequence of excavation at Maheswar and Navdatoli,[12] on the Northern bank of the Narmada, can be divided into seven phases beginning from Early Stone Age to about the Muslim-Maratha period. Of these, though glass was known to the Maheswar people of periods IV and V, 95% of the glass bangles are restricted to the layers of period VI (c. A.D. 100-500). The dating of these layers was done by C^{14} test. The specimens are glass beads, bangles (both polychrome and monochrome, discs, seals, pieces and slags etc., with varieties of shapes.

Nasik

Four stratigraphical phases of Nasik,[13] on both the banks of Godavari, cover a period from Chalcolithic or Early Bronze Age (500 B.C.) to Mughal-Maratha periods (1875 A.D.). The chronology of the strata and structures has been determined by coins, inscriptions on potsherd and other objects. The varieties of glass materials are beads, bangles, rings and other miscellaneous objects. Both Polychrome and Monochrome glass bangles were recovered almost in the same quantity from all layers. Green, blue and white appear to have been the most popular colours.

Kolhapur, a glass-making centre

Of the four different layers of a mound on the western outskirts of the city of Brahmapuri[14] (Kolhapur on the Panchganga river), the first layer (i.e. Bahmani period —1435-1518 A.D.) has supplied varieties of glass objects (e.g. beads, bangles, rings, etc.) with different colours and shapes. The glass, obtained at Kolhapur, is of very good quality and is generally very well preserved. The presence of glass slags and the number of unfinished beads at their various stages of manufactures shows that there was a flourishing bead-making industry at Kolhapur. Besides a huge quantity of bangles, complete, incomplete and fragmentary types also suggest the presence of a glass bangle industry, perhaps on the mound, where excavation was conducted. In

addition, a good quality of glass wires, glass slags, ashes mixed with lime and parts of a kiln were found in different parts of the excavated areas.

Nevasa, a centre of glass-industry

The materials, found by the excavations at Nevasa[15] (on the Pravara, a major tributary of the Godavari), have been grouped into six phases extending Early Palaeolithic to Muslim-Maratha peirod (1700 A.D.). The real indigenous workmanship, however, is at its best in the glass materials of Phase VI from where large number of glass beads and bangles were unearthed. The period may be dated to about 14th to 18th century A.D. (Muslim-Maratha period) on the basis of the evidence of Tughlaq and Bahmani coins. It is interesting to note that though glass was known during the period of Phase IV, it developed as a cottage industry only during the period of Phase VI. The glass specimens are beads, bangles, rings, vessels and slags with varieties of shapes and colours. Beads are mostly green, blue and yellow in colours with their different shades. Beads with gold-foil and with lemon yellow matrix were also recovered. The colours employed in the case of Monochrome bangles show a limited range, such as black, yellow, green, blue and red. Black glass bangles are most abundant in late phase of Period V and in layers of Period VI (1,400 A.D. to 1,700 A.D.). The bangles with plano-convex triangular section were most abundant. Polychrome glass bangles may be divided into following categories on the basis of colour of the main basal band of glass such as yellow, red, black, green and blue. Both Monochrome and Polychrome glass rings were recovered. The Monochrome type are grouped basically in four colours namely black, green, red and blue and are mostly opaque with varieties of shapes. Polychrome glass rings may also be sub-divided into varieties of sections such as plano-convex, triangular and round with different shades of colours like persian green, burnt sienna, sap-green, light grey and ultra-marine blue. Glass slags from topmost layer indicate that there was a glass-making industry. Varieties of different coloured slag specimens suggest that the glass-makers were quite skilful and careful workers.

Kancipuram

The excavation of the deep deposits of Kancipuram[16] in the district of Chingleput reveals two cultural periods with sub-divisions in Period I. Glass beads and glass-bangles have been recovered from Period II (i.e. of the medieval period) in association with the thick dull-red pottery.

Ahmednagar

The discovery of eight green and greenish blue glass flasks along with thirteen Chinese porcelanious bowls at Baluchipura[17] ward of the old Ahmednagar city in the Maharashtra State is another interesting example in the history of glass technology. As the date of these Chinese bowls is definitely evidenced from the inscriptions of the Ming period, their associated glass flasks also belong to the same period (1590 A.D.). This is further supported by the Chinese account which narrates a good trade connection between China and India during this period. The flasks are on the sides with a semi-

circular or round body and a tall cylindrical neck, which show that they were blown and the rims were tooled to form a cavity inside the neck. Impurities like seeds and speck of sand are found to adhere to the body part of these flasks and a whitish film is visible on their surface due to devitrification. A sticky blackish residual substance within the flask demonstrate that they were possibly used as wine-flask.

III

Glass specimens of the Mughal period,[18] preserved in the different Museums of the world, clearly show the Persianising influence in art and design. It was during the Mughal rule many Persian craftsmen came to India and played an important role in the manufacture of the glass articles by adding new designs and delicacy. Thus it ushered a new era in the history of glass technology. Some of these specimens were imported in the Indian market for trading purpose. The specimens of the Mughal period may be grouped into following categories—(*a*) *hukkah* bowls with varieties of shapes– chambu shaped, flat-bottomed and free-standing, etc.; (*b*) dishes and dish cover; (*c*) spitoons; (*d*) mirrors; (*e*) spectacles and (*f*) other miscellaneous objects.

Most of the Mughal specimens, as could be judged from an examination of their appearance were possibly made by the blowing process; but the glass was not quite pure being full of air bubbles and seeds. Specimens of Mughal glass of the later period are found to be more particularly opaque than the earlier ones. In the earlier Mughal specimens of the blue coloured glass copper was preferably used as colouring agents, while cobalt was widely used for this purpose in the later specimens. Green and gold seem to be the most favourite combination. Bright opaque lemon-yellow glasses are abundant among the later Mughal specimens and process of gilding seems to be very common in this period.

Some Dutch and English specimens are characterized by distinctive Indian designs and were freely imported to Indian market.

Glazed earthen ware tiles are abundantly found in many masks and palaces of the Mughal period. The composition of glazes, as is well-known, corresponds to that of glass. These glazes are also often coloured with addition of various colouring agents.

IV

Technique of Glass Making

Inspite of numerous references to glass objects and their uses in many literary works, there is little information on record regarding technique and varieties of tools and implements used for their preparation. However, the specimens unearthed at different archaeological sites indirectly provide some idea about the techniques of their preparation—modelling, moulding, blowing, annealing etc.

Raw materials

The raw materials for the preparation of glass may be of two types: (*i*) fundamental constituents, (*ii*) colouring agent and miscellaneous additions. The fundamental materials used for making of glass in almost all parts of the world since the earliest times are mostly of soda, lime and silica, which can be drawn out into threads, blown thinner and can easily be moulded. Potash and oxides of lead are also found in many samples at somewhat later date. For the purpose of colouring glass appropriate metallic oxides were used in addition to fundamental constituents. Colours vary from deep to light shades due to variation of quantity of colouring agents and the temperature of fusion. The common practice of removing any tinge of colour in the glass specimens due to any impurities is to add a colouring agent (e.g. manganese dioxide, nickel oxide and selinium) that produces a complementary colour.

Chemical analysis

The chemical analysis of the specimens of about eighteen areas (e.g. Taxila, Kausambi, Ahicchatra, Kurukshetra, Kopia, Nalanda, Rajghat, Tripuri, Kolhapur etc.) shows that the Indian workers were well-acquainted with the raw-materials and colouring agents used for the preparation of glass, plain and coloured. In some of the specimens of Taxila glass the presence of lead oxide and in some of the Tripuri specimens (200 B.C.) the presence of barium oxide have been found. It is now well-known that the presence of lead in glass gives rise to the formation of crystal glass and that of barium imparts to glass of high resistance to heat. These seem to suggest that the Indian workers were also aware of this fact much earlier than the Babylonian and glass makers of few other countries like Assyria and Rome. The presence of SnO_2 and Sb_2O_3 in some of the Taxila specimens also suggest that the ancient Indian glass workers were aware of the use of these substances in glass as opacifying agent. Quite a large number of glass specimens contain high percentage of SiO_2 like 60 to 80%.

Furnace, Oven

From an early period (i.e. during the time of Mohenjodaro), charcoal was used as fuel and the heating temperature could not be more than 1000°C. Even at a much later date in the sixteenth century the glass industry in India had not advanced beyond crude stage, due primarily to the inefficiency of Indian furnaces, which are incapable of producing sufficiently high temperature. Regarding the glass furnace in ancient India, our information is however meagre. The descriptions of the furnace that we find in the report of the excavation of Mohenjodaro are mostly used as pottery-making of which a large number have been unearthed. A glass-making kiln (*c.* 3rd to 4th century A.D.), the description of which has been recorded in the report of archaeological excavation at Nevasa,[19] is a circular oven of 2′-6″ in diameter with 1′-7″ in depth and is made of burnt clay. Around it was found an abundance of bichrome glass, slag lime, cowdung etc. The excavation at Lothal,[20] near Saurashtra, reveals a circular furnace of 6′ in diameter with a roof having four openings. The surface of the oven is plastered with mud. It might have been used for heating the raw bead-materials and half-finished beads.

It has been remarked by C. S. Fox that most of glass furnace in ancient India are open-fired type, using solid fuel and melting was carried out in clay pot.

It might however be pointed out here that the evidence of large scale glass-making of much earlier date like those of Kopia (5th century B.C.), Taxila (7th century B.C.), Maheswar, Navdatoli, Nevasa, etc. has been obtained as a result of archaeological excavation at those places, as stated before. It is quite likely that the more improved pattern of kiln using clay pot might have been employed at those places.

As regards crucibles our evidence is very meagre. At Mohenjodaro,[21] we have found several pieces of pottery that appear to have been used either in connection with a kiln or, in one case at least, as a crucible.

Glass pots and muffles

One is thickly coated with a mixture of sand and clay, and there can be no doubt that it was used as a pot for melting glass. Mackay is of opinion that it served either as a crucible or, more likely as a muffle for firing glaze is a thin pottery plate, 4.17 in. in diameter and 0.2 in. in thickness. It has a thick cement of mud and straw round the edge which shows signs of burning. This plate, was evidently used to seal up the flue of a furnace. Similar pieces with a similar cement are used for the same purpose in India at the present time. A small open vessel, which was found with two others of the same shape and size is covered with a grey paste that was heavily fired apparently more than once. This vessel, which has a fairly smooth interior though with a rough outside may have been used as a kind of muffle. Specimens unearthed from Kopia,[22] a place about 31 miles from Basti in Uttar Pradesh, include beads of numerous shapes, sizes and patterns, lumps of glass separately and also sticking to pieces of what can easily be recognized to be parts of some clay container or crucibles which might have been used for heating or melting process. Dr. M. N. Nagar, curator of the Provincial Museum at Lucknow, is of opinion that the mound of Kopia (extending about a mile and rising about 40 ft. from the surrounding fields), scattered over with innumerable glass beads and glass pieces of various shapes and sizes, was the site of an ancient glass factory of about 5th century B.C. The clay pieces, supposed to be the parts of container or crucibles, are reddish brown in colour, hard and stone-like to touch and when examined in section appear to have characteristic structure. From the appearance of these pieces one gets the impression that perhaps a laterite clay was used for making them and on verification this proves to be a close-grained, hard reddish brown, stone-like body.

Modelling

The earliest glasses were modelled[23] on a sand-core. In such a process the glass batch (the raw ingredients of the glass before fusing) is fused in a clay crucibles and allowed to cool, the defective parts were chipped off and discarded and lumps of metal (unworked glass after the fusion of the raw materials) were re-heated so that it might be rolled out into rods. A core of sand was affixed to a tapering metal rod

and the vessel was modelled by winding the glass rods spirally round this core. The surface was then smoothed by rolling the glass on a smooth surface, when the vase was completed the metal rod and core sand were removed; examples of this early glass almost always show a coating of sand on their inner surface, an indubitable proof of the technique employed. This process is trouble some and ill-suited for the production of large vessel.

Moulding

In the second process molten glass is poured and pressed into a mould.[24] The ancients from very early days understood the use of moulds for objects of clay and metal. They also adopted the process for glass. The production of glass in a crucible would show that when cold, it took the shape of a crucible.[25] Among the glass specimens of ancient India like beads,[26] heavier or large objects were made by moulding. In their devitrified state the irregular masses in structure clearly indicate this feature in early glass. It is not possible to get a correct idea about the material for these moulds. It was sand moulds which could naturally be destroyed when the objects enclosing them were extricated. But it is also possible that some of them were of reddish sandstone. Many examples of these were found at Ter and Paithan.[27] At Prakash[28] monochrome translucent variety of glass-bangles with pentagonal section seems to have been manufactured by the use of a mould. A flattish tile with depressions for square beads is derived from Kolhapur also. At Kondapur,[29] the bead is made by taking two shades of pale blue glass and swirled with a layer of milky white opaque glass between them. These are then moulded into a bead. This leaves a brilliant white zonal line in central portion. It is possible that these moulds were used by goldsmith for repousse work in metals: but those intended for glass may not be far different.[30]

Blowing

The next development in the glass industry was the invention of glass-blowing towards the end of the first century B.C. It was the most revolutionary one ever made in the history of glassware. It is quite natural that the invention of glass-blowing began by blowing glass into a mould and then developed into free blowing. The fragments of a very fine bowl of first century B.C., discovered at Taxila, reveal its preparation. This was made by taking canes made of threads of white and colourless glass, which has been twisted together so as to form a spiral and then winding the canes, when plastic, round the inside of a mould and fusing them together with heat and pressure. To form the rim a piece of blue and white glass has been used.[31]

Tools and implements

Before giving picturesque description of the making of glass pickle-jar or *achari* at Lucknow during eighteenth century, as given by Dobbs, we have to discuss first the tools for working molten glass for bangles and bowls, used in India at the present time also by workers in the countryside.

Ankri or *adhkar* or *unkri* or *upri*.[32]—This is an iron rod about two feet long

hooked at one end and fixed on to a wooden handle at the other. It is used for stirring the molten glass and taking it out of the crucibles. *Aarag* or *sallakh* or *suja*—This is a long pointed spit of iron of uniform thickness. *Mala* or *bala* or *thapi* or *pathia*—This is a moulding and pressing tool of iron, shaped in some districts like a big spoon, which is used for taking out metal, while in some other districts it is shaped as a heavy blunt dagger. *Tokla*—It is an iron rod with a thick butt tapering off to a point. *Bardhana* or *barauna* or *bidarka* or *unar*—This is a short piece of stout iron wire fixed into a light bamboo handle at one end and sometimes hooked, sometimes straight, at the other end. It is inserted between the inchoate bangle to prevent its sticking to them. *Chitarna*—This is an iron rod used in Saharanpur and Etah for twisting the molten glass for certain kinds of bangles. *Kalchul* or *karchuli*—This is an iron ladle used for transferring the molten glass from one crucible to another. *Kalbul* or *sundar* or *surtari*.—This is a clay cone fixed on to an iron handle for shaping the bangle. In Punjab the instrument is called *sarbandi* and *salendhi*, *sarkandi* or is known as *kalbut*.

Tools for the blown articles

Nal or *phunka* or *dhotali*—an iron blow-pipe, usually a piece of an old gun barrel. *Kund*, or *sarhendi*—A solid bar of iron which is attached to the bottom of the bubble of glass when blown. *Mala*—A dagger-shaped pressing instrument. *Masa* or *masha*—Pincers of stout iron wire, shaped like a big hair-pin, used for working the rough edges of an article to shape and separating it from the blow-pipe. *Chimla* or *ambar*—Broad iron tongs for placing broken pieces of glass in position in the furnace. *Sikh*—Iron spit for stirring the melting-glass. *Sil*—Slab stone on which the end of the blow-pipe is rolled round the squeeze together with the pieces of glass picked up.

The process of blowing is practically the same as in European and country glass. The following is a description of the making of glass pickle—jar or *achari* at Lucknow during the eighteenth century, as given by Dobbs.[33]

There are two workmen engaged at the furnace. A broken tumbler is placed on the floor of the front melting compartment at the edge of the hole through which the flames of the fire are shooting up. After about five minutes the first workman takes it up with the tongs and attaches it to the end of the blow-pipe, which he has previously smeared with a gum made of saltpetre, borax, arsenic and water. He then hands it on to the second workman, and receives from him a second blow-pipe with a fused mass of glass attached to its end, which he will blow and shape while the fragment of the tumbler is in the hands of the second workman. The latter holds the fragment of the tumbler over the fire at the end of the blow-pipe for about five minutes until it is thoroughly fused, when he takes it out and rolls it round on the stone slab, putting it into a round ball with the dagger-shaped tool called *mala*. After this he plunges it into a jar of water to cause all the air bubbles to escape, and fuses it again over the flames for another five minutes. He then hands it over to the

first workmen, who warms once more and then blows into the pipe for about ten seconds till a bubble—one inch long—protrudes from its end. He repeats this warming and blowing process three times until the bubble is four inches long. Then he places the blow-pipe on the grooved rest in front of the furnace, so that the bubble of glass is over the flames and twirls it rapidly round in order to get the shape even. After this he swings the blow-pipe twice round his head elongating the bubble for centrifugal force, and warm it again. This swinging and warming process is repeated for five times. He then flattens out the bottom of the bubble by pressing it against the side of the furnace. Next he takes the *kund*, a solid bar of iron, and sticks it into the centre of the bottom, making the bottom rise into a cone inside the vessel. The glass bulb is now held between the blow-pipe and iron bar. The workman next takes the tweezers of stout iron wire, dips them into water and grips the stem of the bulb with tweezers almost at the point where the blow-pipe inside the stem ends. The stem cracks round this line under the touch of the moist tweezers and the blow-pipe is left with about three inches of neck round its end, while the main body of vessel is stuck by its bottom to the iron bar, the fragment of the blow-pipe is knocked off and put among the broken glass to be melted up again. The workman now turns the iron bar, to which the incomplete vessel is fixed, on the socket in the screen before the furnace, until the rim is well-warmed. He then takes it out and works the tweezers about inside the rim of the vessel till he has got it to the proper shape. The vessel is then cooled for four hours in each of the three annealing ovens. An article such as a lamp globe, or lamp chimney, which is open at both ends, is not put into the annealing ovens, as the quick contraction in the cool air does not cause it to crack.

Method of fabrication and technique of glass-beads

In an iron container a mixture of powdered quartz or very pure sand with alkali (soda, potash or nitre) and some lime in quantities is heated to fusion to form uniform molten mass. Generally before heating, colouring materials like minerals containing iron, copper, manganese, cobalt etc. were added. When all these thoroughly mixed and molten into a thick syrupy mass, a workman stirs it with an iron bar on the end of which he gathers viscous mass of red hot glass. After this he fixes another bar in the mass and gives the bar to a second one, who runs with it at full speed, pulling the glass mass out into a rod, which solidifies instantly by cooling and appears as a shiny rod, twenty-five to thirty yards long, half an inch thick near the base and becoming perhaps one inch in the middle. This long rod is then cut down to handy lengths of two or three feet. These glass rods or sticks are the raw materials for making the simplest kind of beads, the so-called wire-winded beads.[34]

For preparing wire-winded beads[35] the workmen melt one of these glass rods at one end and then fold the softened rod into ring round a copper or iron wire which they hold in the other hand. When the glass ring is closed round the wire, the rest is cut off and the wire with the glass ring turned and heated till it is nicely round or oval. When three or five rings have been turned round the wire it is laid aside to cool. In cooling, the metal contracts more than the glass and the beads can be

stripped off, specially as the wire has been first turned round in ashes and fine sand. According to the diameter of the wire, a wide or narrow perforation can thus be made in the bead. When the wire tapers, the perforation will also be tapering, which was often the case in the olden days. Then too, the heat often was not strong enough to melt a thick rod of glass and beads were made by winding a rod of one or two millimeter diameters several times round the tapering wire or other core (multiple winding). At Brahmapuri[36] (Kolhapur), several beads seem to have been made by wire-wound process by coiling the softened glass rod round a spoke and twirling it to a requisite shape. Disc beads with a lens-shaped cross section are found made in this way in a very large measure. Careful tooling was required for shaping them into square barrels, square, bi-cone, globular beads and even hexagonal cylinders. In the wire-wound process, the trailing of the glass thread is generally quite perceptible on close examination but in the twirled beads the masses seems to be homogeneous. In all the Indian specimens the wire around which the glass was wound was invariably a stationary one. This is in sharp contrast to certain beads made in Japan where the rod itself is made to revolve around its axis mechanically. Cross sections of Indian wire-winded beads show that they have a rough unfinished surface in the core of the perforations and thus indicate that the process of fabricating such beads was a very slow one.

In gold-foil beads,[37] a layer of gold foil is pressed on a glass matrix when hot and is laid over again with another coating of transparent glass. As the foil is not a good cementing article, the material does not form homogeneous mass and the tendency of the bead is to break at the foil layer.

Most of the beads are generally large spherical or standard barrel in shape and have collar-like effect at the edges where the two parts of the beads are separated by notches of cylindrical shapes. Beads with gold foil have a very wide distribution in India.

The technique of plain bangle

For preparing plain bangles,[38] a few big blocks of crude glass are laid on the floor of the furnace almost in contact with the fire. After being heated for a few minutes they are thrown into the basin of cold water, when they break up into small pieces. These are then transferred into crucibles containing half molten glass along with colouring matters as may be required. When thoroughly fused the mass is transferred into a second crucible for complete melting. The workman then dips the end of an iron hook (*aṅkuri*) into the molten glass and takes out a small ball of the glass enough for one bangle. This he winds up upon the end of an iron spit (*śallakh*) into a thick irregular ring. He then takes up a dagger-shaped tool (*mala*) and resting the end of the iron spit, round which the glass ring is wound up, on stone slab (*patri*) and squeezes the ring with the help of the dagger-shaped tool (*mala*) till it is possibly cooled. The ring is then detached from the spit by means of an iron wire (*barhora*) to which it is then removed. From the end of the iron wire it is transferred to the

tip of a tapering clay cone (*kalbut*). The workman then holds the clay cone towards the opening of the furnace, pressing thin handle of the iron wire between his open palm and the surface of the same slab in such a way that the clay cone is slanted upwards towards the furnace. In his other hand he holds the iron wire which is inserted between the clay cone and the glass ring. Next by rubbing his open palm against the handle beneath it backwards and towards over the stone slab he causes the clay cone to spin rapidly round, and the glass ring upon its tip becomes gradually enlarged and slips down to the broad base of the cone until it has grown to the size of a bangle. It is then slipped off and thrown to cool into the pit between the stone slab and the furnace. At Shahjahanpur and Budaun, the glass ring is transferred from the iron spit of uniform thickness (*śallakh*) to the tapering iron spike (*tokla*) and from that to the clay cone. The use of this additional tool is said to produce more evenly shaped bangles. One skilled workman at the big centres of the trade can turn out one thousand plain bangles in one day, working for nine hours. At the smaller factories the average daily out-turn of a workman is only five hundred a day. Native glass is used everywhere except in Aligarh and Saharanpur, where certain transparent twisted bangles are made of foreign glass.

Bangles or their fragments, discovered from the archaeolcgical sites are both monochrome and polychrome types. The former is more abundant than the latter. The glass, used for these bangles, is generally translucent; in some cases, however, it is opaque and brittle. The workers of monochrome glass bangles had used limited range of coloured glass and also limited range of decoration.

Specimens of those bangles from Maheswar and Navdatoli[39] show that they might have been done by revolving the bangles round some rouletting mechanism. At Brahmapuri[40] (Kolhapur), the simplest monochrome bangle is made by putting out a wire from molten glass kept around the furnace in small crucibles.

Complicated type of bangles with multi-coloured designs and decorations, unearthed from the different excavated areas, indicate the craftsmanship of glass-workers. Bangles from Maheswar and Navdatoli[41] show a varied range of combination of colour design. In some bangles of Maheswar and Navdatoli wires of plastic glass were possibly placed one above the other and subsequently fused to show vertical bands of various colours. In some cases, wires of differently coloured plastic glass were possibly twisted to give rise to spiral pattern. In some others, small lamps of colourless plastic glass were possibly laid over the surfaces of a differently coloured bangle, revealing a design of eyes or dots. In the case of a bangle at Brahmapuri,[42] it was found that possibly two or three thin wires of differently coloured glass were so placed on a thick white band of colourless glass, and then polished off to give a smooth surface, so that it may look like a pointing over a white background. Some bangles of Nevasa[43] show a skilful combination of wires of differently coloured glass arranged one above the other, then fused together. One specimen of polychrome bangle of opaque glass from Bellary[44] shows that after moulding the body part of

the bangle, a pattern was produced by applying a lemon-yellow glaze to its surface. The band of lemon-yellow glaze is lighter than the cobalt blue glass of the body.

Much of the information regarding the tools and implements, and the process and technique employed for making specimens of beads, bangles, bowls and other miscellaneous objects of ancient and medieval India, as described in this article, was collected from the local workers of the present time at the different sites of excavations, which, it may be assumed do not differ to any notable extent from those days. Because, as is well known, the crafts and professions in ancient India were hereditary or have remained hereditary.

REFERENCES

[1] *Rasaprakāśa Sudhākara*, also cited by P.K. Gode, *Bharatiya Vidya*, 7, Nov. 1946, pp. 151-52; *Rasārṇava*, XI, 171. *Rasaratna Samuccaya*, Bk. VII. 8; IX. 69; *Rasaratnākara*, pp. 42, 46, 50, 51, 55, 58, 64, 73, 76, 107, 161, 167, 170.

[2] *Nava Ratna-parikṣā*, verse 180, 182.

[3] *Abhidhāna Cintāmoṇikośa*, pp. 51, 145; *Halāyudha kośa, Kāṇḍa* 4, Sl. 758. *Trikhaṇḍa śeṣa, Vaiśya-varga*, 63.

[4] *Vyāsayogi carita*, Edited by B. Venkoba Rao, 1926. Gode, P.K., 'Some Notes on the Invention of Spectacles in India between A.D. 1500-1800', *Studies in Indian Cultural History*, 3, 1969 Poona, pp. 102-12.

[5] *Ancient India*, **10**, 1954 pp. 8, 28, 90-93.

[6] *Indian Archaeology, a review for 1957-58*, 1958 p. 50; 1960-61, p. 35; 1963-64, pp. 58-59...

[7] *JBORS*, **10**, Pt. III, 1924, Patna, pp. 189-93; **20**, Pt. I, 1934, Patna, pp. 1-6. *Indian Archaeology, a review for 1967-68*.

[8] Altekar, A.S. and Misra, V., *Report on Kumrahar Excavations*, 1951-55, Patna, 1959, p. 132.

[9] *Indian Archaeology, a review for 1961-62*, pp. 3-4.

[10] *Indian Archaeology, a review for 1960-61*, 1961, pp. 17-18; 1961-62, pp. 24-25; 1962-63, 1965 pp. 11-12.

[11] *Indian Archaeology, a review for 1954-55*, 1955 pp. 22-26; cf. also M.G. Dikshit's *History of Indian Glass*, 1969, p. 68.

[12] Sankalia, H.D., Subbarao, B., Deo, S.B., *The Excavation at Maheswar and Navdatoli*, Poona 1958, pp. Preface XI-XII; pp. 180, 186, 215-22.

[13] *Report on the Excavations at Nasik and Jorwe*, 1950-51, Poona; 1955 pp. 1, 27-29, 96-100.

[14] *Excavation at Brahmapuri* (Kolhapur), 1945-46, Poona 1952 Chap. II, pp. 9, 98, 116-17.

[15] Sankalia, H.D., Deo, S.B. and Ansari, Z.D., *From History to Pre-History at Nevasa* (1954-56) Poona; 1960 pp. 1, 64-70, 443-47.

[16] *Indian Archaeology, a review for 1962-63*, 1965 p. 12.

[17] Dikshit, M.G., *History of Indian Glass*, 1969, p. 74. University of Bombay, Bombay.

[18] *Ibid.*, pp. 82-112.

[19] *Indian Archaeological Review*, 1959-60, 1960 pp. 25-26.

[20] *Ibid.*, 1957-58, 1958 p. 12.

[21] Mackay —*Further Excavation at Mohenjo-daro*, pp. 177-78.

[22] *Glass-Industry*, **34**, 1953, pp. 366-68, 392.

[23] *Antiquities*, **7**, p. 420; Singer —*A History of Technology*, II, p. 334.

[24] *Antiquities*, **7**, p. 421.

[25] Singer, *Ibid.*, Vol. II, p. 334.

[26] Sankalia, H.D., *From History to Prehistory at Nevasa*, 1954-56, p. 356; Dikshit, M.G., *Hyderabad Archaeological Series*, No. 16, Bead No. 188, 193.

[27] Dikshit, *History of Indian Glass*, 1967, p. 55.
[28] *Ancient India*, No. 20 & 21.
[29] Dikshit, M.G., *Hyderabad Archaeological Series*, No. 16, Beads No. 203, 188, 193.
[30] Dikshit, *ibid.*, p. 55.
[31] *Memoirs of Archaeological Survey of India*, No. 65, 1941.
[32] Dobbs —*A Monograph on the Pottery and Glass Industries of the North-Western Provinces and Oudh*, 1895, p. 36; Hallifax, C.J., *Monograph on Pottery and Glass Industries of the Punjab*, 1890-91, p. 24.
[33] Dobbs, *Ibid.*, pp. 42-43.
[34] Van Der Sleen, W.G.N., *Journal of the Royal Anthropological Institute*, 88, pp. 204 ff., 207.
[35] *Ibid.*, p. 205.
[36] Sankalia, H.D., *Excavations at Brahmapuri (Kolhapur)*, 1945-46, Poona 1952, p. 100.
[37] *Ancient India*, No. 8-9, 1952 pp. 57-58; Sankalia, H.D., *From History to Pre-History at Nevasa*, 1954-56, p. 355.
[38] Dobbs, *Ibid.*, pp. 36-37.
[39] Sankalia, H.D., *The Excavation at Maheswar and Navdatoli*, 1952-53. Poona 1958, p. 216.
[40] Sankalia, H.D., *Excavation at Brahmapuri (Kolhapur)*, 1945-46, Poona 1952, p. 151.
[41] Sankalia, H.D., *Excavation at Maheswar and Navdatoli*, Poona, 1958 p. 217.
[42] *Excavation at Brahmapuri (Kolhapur)*, p. 151.
[43] *From History to Pre-History at Navasa*, Poona 1960; p. 447.
[44] *Bulletin of Deccan College Research Institute*, **14.** 1954-55, p. 49.