CHAPTER – 2

THE BRASS INDUSTRY

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2.0 **Introduction**

In this chapter, we examine the structure and functions of the mother industry (Brass), of the industry we are concerned with (Brass Part) in the present study. This examination focuses on various aspects of the brass industry, such as: basic concepts and definitions, history, nature of basic elements alloys and metals involved, manufacturing processes and others.

2.1 **Definition of Brass**

Brass is an alloy (mixture) of copper and zinc and with the addition of small amounts of other elements may be added to the alloy for special uses.¹

**Alloy**

A metal made by combining different types of metals is called an alloy. Alloys are made to increase a metal’s strength, to make it more resistant to corrosion and wear to make it lighter and even to change its color. To make it lighter and even to change its color. To make alloys, a metal is melted down and combined with other metal. Copper is a metal used in many alloys because it is abundant,
lustrous and easy to shape. Brass is an alloy which is made by combining copper with zinc.\(^2\)

### 2.2 BACKGROUND

Brass is a metal composed primarily of copper and \textit{zinc}. Copper is the main component, and brass is usually classified as a \textit{copper alloy}.\(^3\) The color of brass varies from dark \textit{reddish} brown to a light \textit{silvery} yellow depending on the amount of zinc present; the more zinc, the lighter the color. The zinc content can vary between 10\% to about 45 \%.\(^4\)

Brass is specified because of the unique combination of properties, stronger and harder than copper, it is easy to form into various shapes, a good conductor of heat, and generally resistant to corrosion from salt water. Because of these properties,\(^5\) Brass is usually the first-choice material for many of the components for equipment made in the general, electrical and precision engineering industries brass is also used to make pipes and tubes, weather-stripping and other architectural trim pieces, screws, radiators, musical instruments and cartridge casting for firearms. Matched by no other material, those make it indispensable where a long, cost-effective service life is required.\(^6\)
2.3 HISTORY OF THE BRASS INDUSTRY

The discovery of metal changed the lives of the people in the ancient world. Metal and its alloy made agriculture easier, providing farmers with more efficient tools to work their land. Armies that possessed metal knives, swords, and shields were no match for those that did not. The first two metal and its alloy widely used by humans, copper (and its alloy brass) and gold are still important in people’s lives today.\(^7\)

A world history of brass industries

Ancient people were our first “geologists” and “miners.” They not only determined which rocks were best to use, but they learned how to make them into tools, hunting spears, arrows, fishhooks and ornaments.\(^8\) Shaping the stone was done by flaking it with sharp Blows on the edges using another stone or deer antler. Flint (Stone) was one of the purist’s native forms of Silica. It was hard and having dense minerals, so it was used for making weapons. Man’s first use of the Earth’s natural resources was in the form of grasses, trees, animals and stone. Tools and weapons were made from wood, bone and stone.\(^9\)
Stone-Age people knew nothing of metal. Colorful minerals were used for decoration or for barter\(^\text{10}\). When emerald-green malachite (a copper ore) or a rusty-red hematite iron ore were found, they would be ground to a powder and used as pigments to decorate the face and body. They also used these and other colorful minerals pigments to paint the walls of caves and protected coves. Today, many minerals are used for paint pigments.\(^\text{11}\)

Can you imagine how excited these people were when they found native copper? Copper is one of the most useful of the metals, and probably the one first used by man.\(^\text{12}\) It is found native and in a variety of combinations with other minerals. It is often a by-product from silver and other mining. Copper has many colors from yellowish-to-reddish brown, red, pink, blue, green, and black. The colors are determined by the other elements (minerals) combined with the copper. From 4,000 to 6,000 BC was the Chalcolithic period which was when copper came into common use.\(^\text{13}\)
Transition from the Neolithic to the chalcolithic periods occurred in more than one geographic area, as archaeo metallurgical evidence suggests that copper smelting was discovered independently in many different part of the world. For example, excavation at Rudna Glavia in Yugoslavia revealed that a large underground mine was in operation there before 4000 B.C.\(^4\)

One of the most ancient people in World history, the Sumerians, probably obtained their first supplies of copper from the mountainous country surrounding Lake Van in Armenia.\(^5\)

Egyptians probably drew their first supplies of copper as native metal and from the abundant. Malachite stones found in the hills near the Red Sea in the Eastern Desert. The Egyptian mines lay almost on the natural trade route to the Red Sea.\(^6\)

Around 2800 B.C., traders in Cyprus were receiving copper objects from Egypt and similar articles bearing cuneiform inscriptions probably from Sumerian. At about the same time Cyprus developed its own copper mines. These became renowned throughout the Eastern Mediterranean. Copper has a chemical symbol, as do all elements. The symbol for copper is Cu and comes from the Latin
cuprum meaning from the island of Cyprus, which provided an abundant sources of copper for the ancient world.\textsuperscript{17}

Some ores contain both copper and tin. When smelted, these ores yield an alloy of these two metals, which is known as Bronze. Bronze is significantly harder and stronger than pure copper, and in utilitarian terms at the time, considerably more valuable. The discovery of a copper-tin alloy and its uses led to the Bronze Age.\textsuperscript{18}

The Bronze Age began in Europe around 1500 B.C..\textsuperscript{19} In China, it reached its apogee at about 1529 B.C., during the change dynasty. Whole series of magnificently ornamented, useful, and ceremonial Bronze vessels, exist from that time. Tin ore coexisting with copper appears in Turkey and Siam in Asia and in Wales and Spain, in Europe. Phoenicians probably brought bronze ingots from Europe to Egypt. The cake-shaped ingots were a few centimeters thick and were cast with a rounded profiles shaped to rest on the backs of the men who had to carry them. They can be seen on Egyptian Frescos and Persian reliefs.\textsuperscript{20}
Bronze is easier to cast than pure copper,\textsuperscript{21} once the Egyptians had learned to alloy copper with tin, and frequently also with a little lead improve the metal’s solidification characteristics, casting became a much more viable process, products began to include such diverse items as axes, bowls, tools of many kinds, weapons, celts, figurines, large vases, and sacred vessels.\textsuperscript{22}

Ancient Greeks also used bronze to a considerable degree.\textsuperscript{23} In Greece, hundreds of types of products were unearthed ranging from exquisite little figures used as the supports or handles of mirrors and caskets to large products such as statues and armor plates.\textsuperscript{24}

Somewhat later in history, \textit{Romans were the first to use brass, as alloy of copper and zinc}, on any significant scale, although Greeks were already well acquainted with the metal in Aristotle’s time (330 B.C.) Greeks knew it as “Oreichalcos” a brilliant white copper, which was made by mixing tin and copper with a special earth called “Calmia” or calamine. Calamine was an impure zinc carbonate, which was rich in silica and found on the shores of the black sea. To make brass, ground calamine ore and copper were
heated in a crucible. The heat applied was sufficient to reduce zinc to the metallic state but not high enough to melt copper. However, zinc vapor permeated the copper and formed the copper and formed brass, which then melted.\textsuperscript{25}

In antiquity the words \textit{bronze} and \textit{brass} did not exist. \textit{Brass} is an English word derived from \textit{braes} (Old English) and \textit{bres} or \textit{bras} (Middle English) about 1200 AD\textsuperscript{26} In the language of Tudor England, \textit{brass} stood for any copper alloy, and the King James Bible uses the word in that context. Joseph Smith, favoring the King James Bible, translated the Book of Mormon using \textit{brass} in the same manner.

Roman used brass for personal ornaments and for decorative metal work alloys used contained from 11 to 28\% zinc, and the value of different grades of brass for different purposes was clearly known. Greeks used only a few copper coins, but Romans had a large variety of copper money.\textsuperscript{27}

The middle ages and Renaissance: During the early middle ages, much of the early use of Brass served military purpose. Must have
Proven to be quite valuable when cannons were introduced, brass cannons were used by German armies in Italy, at the siege of Cividale in 1331. Brass cannons used Edward-III at Cambria in France and Crecy may have led to the establishment of a metallurgical industry in England soon afterward. The first record of manufacture of brass guns in England was in 1385, when three such cannons are said to have been made by the Sheriff of Camberland.

Medieval uses of brass were certainly not limited to ordnance. Early artistic applications included brass bells and the well known Baptistery doors at the cathedral of Florence. Copper and brass also formed the basis for decorative enameled ware, including amphorae, jugs, plates, and other functional as well as artistic items. Among the best known examples of this art form were those produced in Limoges, France during the 15th and 16th centuries?

In the middle ages, brass craft also flourished on a grand scale throughout the orient. Central and south Indians temples contain many fine brass including large and small Buddhas. Some of the
immense Buddhas and bells that can be found in India, China have caused artisans many headaches, but once successfully cast, they proved to be durable, having survived to this day.

The temple of Ananda at Tirumalai, India is unique in the sense that it foreshadows modern trends. This Temple is entirely sheathed in brass sheets containing elaborate hand-wrought ornamentation. It presenting parallel to the use of brass wall sheathing on a number of today’s buildings.

In Japan, the most ancient brass products are copper bells, known as “dokatu” which have been unearthed in many places. Because similar products have not been discovered in China and Korea, dokatu is believed to be an original product of the oldest brass industry in Japan. On the other hand, brass products such as swords, utensils and mirrors were imported to Japan from China in ancient days.²⁸

Therefore, it is assumed that in early times a major portion of brass raw materials was imported. The Americas, Aztecs, Toltecs,
Zapotecs and mayas of Mexico and central America and Moche, Nazca, Chibcha, Quimbaya, Chimu, Chanzay, Tiahuanaco and Ineas of central America and Peru al apparently possessed a fairly advanced knowledge of metal working.  

Techniques of smelting, casting, beating, soldering and gilding were understood, and most of the output of metalworkers, who were organized in separate guilds appears t have been in the form of ornament. Some utilitarian objects have survived. Those in copper include fish, hooks, needles, pincers, mirror frame small picks, chisels, and axes. Ornamental clapper less brass bells have been found in sites all over Mexico and Central America.

North American Indians also used brass for tools, weapons, ornaments and amulets. The metal used was probably native copper, which was and is still abundant around the shores of lake superior a number of copper artifacts were discovered, mainly in burial mound during the last decades of the 20th century.
The Industrial Revolution:

The industrial revolution brought about a tremendous change in the production of copper and its alloy, beginning with a demand for more and better raw material. Mine production rose as steam–driven pumps were applied to remove water from diggings. Smaller throughput increased as well, largely due to faster remove of impurities from ore.  

Demand was driven by technical developments, most important of which concerned the use of electricity in 1729 Stephan Gray used brass wire for the first known attempt to transmit an electric current. In 1747, Sir William Watson succeeded in transmitting a current 735m (2410 ft) across Westminster Bridge using the Thames River as the return wire. This, among other experiments, proved that metals were the best conductors of electric fluid as it was called and that of these, copper, even in its relatively impure state was superior to all others except Silver. It is most likely for this reason that Benjamin Franklin used copper for lighting conductors, an application in which it has been virtually unchanged.
In 1811, copper wire was first employed to protect the most of a ship from lighting.

Alessandro Volta assembled the first electric battery in 1799. His invention comprised discs of copper and Zinc pleased one upon the other with a layer of wet cloth between each pair. The development of large, powerful batteries led directly to the invention of the electric telegraph and, in turn to today’s Communication industry it also created the first large industrial demand for copper wire.32

Another significant increase in demand for brass was brought about by the development of the stamping press, which helped speed up the production of simple brass articles. Metal buttons, for example, suddenly became much more readily available, as did many of the brass furniture fittings used by the master cabinetmakers of the period.

Brass has long been the first material of choice in the construction of measuring instrument for use of sea or in any moist, salt-laden atmosphere. This is due not only to the corrosion resistance of brass.
but also to its good machinability, ease of engraving and perhaps most important of all, the fact that it is nonmagnetic, it is because of the latter property that marine compasses are mounted upon brass binnacles, equipped with brass compass bowls and strung in brass gimbals.33

Electrical engineering in the modern industrial series followed from Faraday’s discovery of electromagnetic induction in 1831. Invention of the electric dynamo by Wernervon Siemens in 1866 led to a tremendous increase in demand for copper to supply electric power this became particularly evident during the second half of the 19th century after Edison’s invention of the electric light bulb in 1878 and his construction of the first electric power generating plant in 1882. Installation of land and submarine telegraph cable and use of electric traction motors for train were among many important consequences of rapid progress in electrical engineering during the second half of 19th century. All of these developments naturally made growing demand on the supply of copper and its alloy brass.34
Brass is a metal composed primarily of copper and zinc. Copper is the main component, and brass is usually classified as a copper alloy. So, hire we discussed about copper demand, consumption and production of the world.

The Modern Era
The enormous growth in world copper demand between 1850 and 2000, this growth was initiated by a series of advances in copper using technologies, Whereas total demand at the end of the 19th century was about 500,000 mT. 1992 forecasts of world copper consumption were 14,630,000 mT. for the year 2000 and 17,900,000mT. for 2005.\textsuperscript{35}

Toward the end of the 20th century, consumption of primary copper products had climbed to a yearly average (1986-1990 figures) of 8.9 million mT. The 1994 world total consumption reached 13.4 million mT. For the period 1996-2005, copper consumption has been estimated to grow at an average rate in excess of 3%. The largest increases are anticipated to occur in construction, transportation and the electrical and electronics industries. It is also
expected that the large growth in demand will occur in the Asian market.36

**World Reserves**
The largest and commercially most important deposits are those in the mountainous spine of south America and western north America, principally in the United State and Chile but also include Canada, Mexico and Peru, large and important deposits are located in south central Africa, principally in Zaire and Zambia. Together, north and south America and Africa contain more than one half of the known copper deposits in the world. However, Europe (primarily Russia an the confederation of Independent states of CIS) and the pacific Rim (Chiefly Australia and Papua New Guinea) also contain copper mineralization. South America holds the largest shares of both reserves (31.1% if the world total) and reserve base (18.5%). North and Central America follow, with 22.7% and 24.9% of world reserves and reserve base, respectively. Among individual countries, Chile has the largest fraction of the total reserve base at 19%, the United States ranks 2nd with 18%; the C.I.S and Zambia each have 7%; while Canada Peru, and Zaire each account for 6%.37
3.2 Brief History of brass industries in India

The story of Indian Brass as is generally known began during the age of the Indus Valley civilization i.e. around 2400BC to 1700BC.\textsuperscript{38} The extraction of this spread to other sites such as Kalibangan in Rajasthan, Lothal in Gujarat and Laimabad in Maharashtra. The two most well known sites are of course Mohanjodaro and Harappa. The Harappan figure of a dancer, with her carfree stance, is one of the first metal sculpture pieces discovered in India.\textsuperscript{39} The large Buddha figure at Sultanganj is possibly the largest surviving metal work of ancient time and is a monument to the skill of Indian craftsmen in melting and casting metal.\textsuperscript{40}

As per the literary evidences, indicates that the mining and metallurgy of copper and zinc commenced in 2\textsuperscript{nd} century B.C. (Maurya Sanga time), evidence for the continuity of the activities during Kshatranas period of 2\textsuperscript{nd} to 4\textsuperscript{th} century A.D. During the period metallurgy has advanced step by step by fits and starts, condition by the mineral resources of the area and the technological innovation.
of the people. There is also evidence of copper metallurgy from Pre-Harappan level in Sindh and Panjab. There is great spurt in copper metallurgy during the Harappan period (2300 – 1750 B.C.) in various parts in India. After demise of Harappans, copper metallurgy undergoes retrogression, as represented by Chalcolithic cultures (Ca 2000 – 1100 B.C). There is again greater activity in copper metallurgy as represented by copper Hoard cultures (1100 – 800 B.C) in Bengal, Sonepur and Chirand (Bihar) and Atranjikhera, Hastinapur, Kausombi and Rajghat(U.P.)\textsuperscript{41-42}

There is evidence of large scale mining and smelting during this time the major copper sources of the area in Rajasthan, M.P., Mysore, Andhra Pradesh and Bihar. Copper is one of the most widely used metals of antiquity. Pure copper is relatively soft metal and as a result, it was never particularly effective as a material for making objects at utility and art, It can, however, be considerably hardened by mixing with other metals, such as tin, lead, zinc etc. when copper is alloyed with tin, it is known as bronze and when copper is alloyed with zinc, it is known as brass.\textsuperscript{43}
Copper is called ‘tamba’ in Hindustani, Zinc ‘jasta’ and tin pewter is ‘ranga’.\textsuperscript{44} Two or more of these metals are utilized in the manufacture of the alloys used in India. Brass is made from copper and zinc in varying proportions, usually two of the former to one or one and a half of the latter. Bharat, Kaskut or Kansa are the most constant of alloys of India. On account of its bright colour and the polish that it takes this metal is in great demand for ornamental purpose.\textsuperscript{45}

As regards coins, both brass and bronze were used in ancient India for coinage, circular punch-marked brass coins of Dhanadeva and Aryavarma of Ayodhya (1\textsuperscript{st} century BC) have been found, brass coins of kings of several other dynasties living at that time have also been collected. From these archaeological and numismatic evidence it is clear that brass was in common use in ancient India during the first century B.C.\textsuperscript{46} A small number of die-struck coins of the Pre-Gupta and Gupta periods, including a piece attributed to Chandragupta-II, are considered to be made of brass.
Despite the very early occurrences of accidentally produced brass in India, Earlier in India the artists basically showed their inherited talent in various stone carvings in and around temples. But later when brass became common they began experimenting with this material. The ruins of the Vijaynagar Empire at Hampi are the perfect examples of brass work brought in to focus by the ancestors of Pembarthi craftsmen. Though being one of the finest arts of India, it has somehow managed to survive only in the small village of Pembarthi.

The earlier products made out of bronze include the utility items like utensils, statues of Gods and Goddesses besides various other decorative items. The manufacture of household utensils in gold and silver is restricted to a few centers since the demand is comparatively limited but that in brass and copper forms an extensive industry all over the country. Each of the states has two or three centers noted for their copper and brass ware and accordingly, a corresponding number of widely different art conceptions are practiced in the ornamentation of these metals.
India is the largest brass-making country in the world. This art has been practiced in India for over 5 million years. In the field of brass work a variety of styles are seen in different parts of India.

The Northern & North Eastern industries of brass include Moradabad, Aligarh, Hathras and Varanasi in Uttar Pradesh; Mayurbhanj, Dhenkanal, Keonjhar and Sundergarh in Orissa; Jaipur and Jodhpur in Rajasthan; Jagadhari and Rewari in Haryana; Udhampur, Sambha and Bhansali in Jammu & Kashmir; Kurkhihar in Bihar; Hazo and Sarthebari in Assam; Purulia, Bankura, Birbhum, Murshidabad in West Bengal and Delhi etc.

The important clusters of the brass in the Southern and Western regions are Pembertha and Hyderabad in Andhra Pradesh; Bidar, Negamangala, mysore and Gadag in Karnataka (Bidriwar); Swamimalai, Nachiarkoil, Madurai, Kumbakonam, Tirupur and Tanjore in Tamil Nadu; Ambarnath, Thana, Kalyan and Nasik in Maharashtra; Trichur in Kerala; Jamnagar in Gujarat and Pondicherry, etc.
Moradabad in Uttar Pradesh is world famous for its range of brass items. A wide range of household items like pots, trays, bowls and decorative pieces are made here and are decorated with intricate etching. Electroplated brass and copper items and items made of white metal are also created in Moradabad. Banaras is known for cast sculptures of deities and household utensils made of brass and copper. Varanasi, in Uttar Pradesh is the first city in India for the multitude of its cast and sculptured mythological images and emblems in brass and copper as well as household utensils.

Mirzapore is now one of the most important centers of the brass utensils industry in Uttar Pradesh. It supplies the needs of a large part of the State and even exports articles of household use to other Countries.

Lucknow has specialized in articles of use showing distinct Muslim influence, usually profusely ornamented in a shallow repose using animal and flower motifs and pierces designs.
Brass and copper utensils from the staple of the metal works in the Punjab and all large cities great quantities of cooking utensils, lamps etc. are made for local consumption. Amritsar, Ambala, Ludhiana and Jullundur, all supplies brass vessels to the hilly regions round the Punjab and formerly also exported up the Kabul Valley into Afghanistan.

Bihar and Bengal produce an extensive range of domestic vessels in brass and bell metal especially in the region of Malda, Patna and Gaya.

The Ladakh region of Kashmir is known for traditional vessels made out of iron and brass. The craftsmen of Kashmir are also known for richly engraved traditional household items like bowls, samovars, plates and trays. Intricate floral and calligraphic patterns are embossed on copper and silver items. These items are then oxidized, which makes the design to stand out from the background. This work is known as 'naquashi'.
Making of bronze sculptures is common in Palitana in Gujarat. The sculptures made here depict themes from Jain religion.

In Rajasthan Jaipur is the main center for brass engraving and lacquering. Items such as photo frames, bowls, plates, boxes etc. Ethnic designs and floral patterns, hunting scenes etc. are hammered or embossed on the surface. Lacquered designs either cover the entire body or a part of the item. Jaipur also known for its bronze sculptures. The art of Koftagari or damascening work is mainly practiced in Alwar and Jaipur, one metal is encrusted into another in the form of wire. Popular articles are swords, daggers and shields.

Madhya Pradesh has its own traditional metal ware tradition. Ornate metal boxes of Bundelkhand, lamps of Sarguja, rice measure bowls and animal figurines of Raigarh, sculptures of Bastar are a few examples of the creativity of crafts persons of Madhya Pradesh.

Andhra Pradesh has a rich tradition of metal craft. Sheet metal work using brass is done in Pembarti, on plaques, containers, vases etc.
From the small village of Budhiti in Srikakulam, comes elegant utensils and items made of brass and other alloys.

The Dokra metal craft is popular in the tribal belts of Andhra, Orissa and Madhya Pradesh. The uniqueness of this craft form is that no two pieces are alike. Small figurines of horses, drummers, tribal deities and plaques are made here. These items are mainly made from brass scrap. Unlike any other metal craft the core of the objects is filled with clay. Brassware from Tamil Nadu comprises of decorated traditional lamps, used in religious functions, while Kerala is famous for its polished brass mirrors.51

That’s why we can say India is famous throughout the world for its subtle copper and its alloy works that are exported to hundreds of countries throughout the world.

3.3 History of Brass Industries in Gujarat

Gujarat has been the home of metal workers from as early as the Chalcolithic copper –Stone Age. Sites of Indus Valley Civilization
spread all over the state and echo, the presence of indigenous technique of metallurgy. It is well known that the Harappan man, whose remnants have been found in abundance in Gujarat, had excelled in forging, hammering and casting of copper and bronze. Aryans to had in all probability, known the use of a metal known as ayas, which later on come to mean iron but had in that period perhaps denoted bronze or copper. One of the earliest and most formidably board of metal east objects of Gujarat is the one discovered at Akota, near Baroda, A metal bell of the sixth century and an incense burner from the ninth century from this board are perhaps the earliest recorded metal objects of everyday art of Gujarat.

The craftsmen of Gujarat have excelled even in the making of utensils. Visit any home in Gujarat and you are sure to find a variety of gleaming copper, brass and iron vessels, each with a shape and form suited to the specific need. Metal lamps, incense burners, boxes for storing betel leaf and nut, nutcrackers, large dowry containers, and votive figurines are other examples of metal work available in Gujarat. The metal artisans of Gujarat are known as kansaras, whose name is derived from Sanskrit word kansu which means bronze. Before the introduction of brass, the use of bronze utensils was very common.
The varied kinds of nutcrackers and religious and other figurines make for ideal souvenirs and gifts.57

Kachchh and Rajkot the famous for metal engravings and ornaments that are considered so typical of Gujarat. Anjar, Sinhor, Surendranagar, Dhrangadra, and Wadhawan are good places to buy brass and iron utensils, cutlery, knives and scissors. You can also watch arrows being crafted here, and pick up knives and daggers with beautiful sheaths and hilts.58

The brass industry of Jamnagar is one of the largest in India. The brass parts industries are mostly concentrated in an around Jamnagar district which caters to the requirement of around 70% of the machine brass component of the country and also in some quantity export to various countries.59 The brass parts industry in Jamnagar supplies to wide ranging industries such as electrical appliances, automobiles, bicycles, electronics, building hardware etc.
As per the account the brass parts industry in Jamnagar above 60 years old. It started around the late 1940s as a result of downfall of the brass button making units. The main cause for its downfall was the lack of automated machines. They were not able to meet the demand for the good qualities of buttons manufactured by them. This was not the only reason the development of nylon buttons in Japan brought down the demand by a huge margin. It was not feasible for the manufacturer to continue in the competitive world of buttons.

With minor changes in the available machinery the brass button manufacturer changed their production into brass parts components. Necessity is the mother of invention. Their led to the development of the brass machine manufacture in Jamnagar. Along with this the casting also developed in Jamnagar. They were able to do it in a very cost-effective manner.  

4. Raw Materials

The main component of brass is copper. The amount of copper varies between 55% and 95% by weight depending on the type of brass and its intended use. Brasses containing a high percentage of
copper are made from electrically refined copper that is at least 99.3% pure to minimize the amount of other materials. Brasses containing a lower percentage of copper can also be made from electrically refined copper, but are more commonly made from less-expensive recycled copper alloy scrap. When recycled scrap is used, the percentages of copper and other materials in the scrap must be known so that the manufacturer can adjust the amounts of materials to be added in order to achieve the desired brass composition.

The second component of brass is zinc. The amount of zinc varies between 5% and 40% by weight depending on the type of brass. Brasses with a higher percentages of zinc are stronger and harder, but they are also more difficult to form and have less corrosion resistance. The zinc used to make brass is a commercial grade sometimes known as spelter.

Some brasses also contain small percentages of other materials to improve certain characteristics. Up to 3.8% by weight of lead may be added to improve machinability. The addition of tin improves
corrosion resistance. Iron makes the brass harder and makes the internal grain structure smaller so that the metal can be shaped by repeated impacts in a process called forging. Arsenic and antimony are sometimes added to brasses that contain more than 20% zinc in order to inhibit corrosion. Other materials that may be used in very small amounts are manganese, silicon, and phosphorus.\textsuperscript{61-62}

5. Further Alloying Additions:

Alloying additions are made to the basic copper-zinc alloys for a variety of reasons:-

- To improve machinability
- To improve strength
- To improve corrosion resistance
- For other special reasons

The very wide variety of standard brass compositions that are available reflect the many ways in which an optimum combination of properties can be tailored to ensure fitness for the desired application.
1. **Lead [Pb%]:**

Lead is added to improve high machinability, good strength and excellent casting characteristics.

The addition most commonly made to brasses to modify their properties is lead, up to 4% of which may be added to alpha-beta brasses to provide free-machining properties. The lead does not form a solid solution with the copper and zinc but is present as a dispersed discontinuous phase distributed throughout the alloy. It has no effect on corrosion resistance. Lead is not added to wrought alpha brasses since, in the absence of sufficient beta phase, it gives rise to cracking during hot working.

The presence of lead in brass has a lubricating effect that gives good low friction and low wear properties utilized in the plates, pinions and gears used in instruments and clocks.
2. **Tin [Sn%]:**

Tin may be added to enhance the corrosion resistance in marine and mining environments. It gives a small increase in hardness and tensile strength.

1% tin is included in the composition of admiralty brass (CZ111) and naval brass (CZ112 and SCB4). As their names indicate, these brasses were developed originally for sea water service, the tin being added to provide improved corrosion resistance. Brass containing tin (not exceeding 2%) is less liable to corrosion in seawater.

3. **Iron [Fe%]:**

When iron is added to brass it produces hard, tough alloy. One of these is delta metal (55% copper, 41% zinc, 1%-3% iron.)

4. **Manganese [Mn%]:**

Manganese is a useful deoxidant, as little as 0.02% present giving stronger, sound castings, good welding characteristics and good resistance to corrosion in marine atmospheres.
Iron and manganese are the most common additions, combining to confer increased hardness, proof stress and tensile strength, with only slightly reduced ductility.

5. Aluminium [Al%]:

Aluminium has the greatest effect in increasing hardness, proof stress and tensile strength. Due to its effect on ductility and microstructure, close control is necessary to obtain the optimum combination of properties. Corrosion resistance is improved by the self-healing oxide film aluminium confers. Moreover, aluminium is added to form a protective oxide film to keep the molten metal clean and reduce the attack on the die materials and readily accept a wide range of surface finishes; have good electrical and thermal conductivities and are highly reflective to both heat and light.

Aluminium brass (not exceeding 3% aluminium) has greater resistance to corrosion than ordinary brass.
6. **Nickel [Ni%]:**

Nickel improves hardness and tensile strength without significant effect on ductility, conferring improved properties at elevated temperatures.

The range of copper-nickel-zinc alloys containing from 10 to 20% nickel and known as "Nickel Silvers" can be regarded as special brasses. They have a silvery appearance rather than the typical brassy colour. In most respects they show similar corrosion characteristics to alpha brasses but the higher nickel versions have superior tarnish resistance and resistance to stress corrosion cracking.

7. **Silicon:**

Silicon increases the strength of brass and is also sometimes included in die casting brasses and in filler alloys for gas welding to reduce oxidation of the zinc and to assist fluidity. Its principal effect from the corrosion point of view is to increase the beta phase content.
8. Arsenic:

Arsenic is often added in small amounts to alpha brass alloys to provide protection against dezincification corrosion.

Above discussed point we can saw in short as under

EXTRA MACHINABILITY

<table>
<thead>
<tr>
<th>EXTRA STRENGTH</th>
<th>EXTRA CORROSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manganese</td>
<td>Aluminium</td>
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<tr>
<td>Aluminium</td>
<td>Arsenic</td>
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<tr>
<td>Silicon</td>
<td>Tin</td>
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<td>Nickel</td>
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<td>Iron</td>
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BRASS
Copper + Zinc

[Source: According to reference no.63]

6. Design

The traditional names for various types of brass usually reflected either the color of the material or the intended use. For example, red
brass contained 15% zinc and had a reddish color, while yellow brass contained 35% zinc and had a yellowish color. Cartridge brass contained 30% zinc and was used to make cartridges for firearms. Naval brasses had up to 39.7% zinc and were used in various applications on ships.

Unfortunately, scattered among the traditional brass names were a number of misnomers. Brass with 10% zinc was called commercial bronze, even though it did not contain any tin and was not a bronze. Brass with 40% zinc and 3.8% lead was called architectural bronze, even though it was actually a leaded brass.

As a result of these sometimes confusing names, brasses in the United States are now designated by the Unified Numbering System for metals and alloys. This system uses a letter—in this case the letter "C" for copper, because brass is a copper alloy—followed by five digits. Brasses whose chemical composition makes them suitable for being formed into the final product by mechanical methods, such as rolling or forging, are called wrought brasses, and the first digit of their designation is I through 7. Brasses whose
chemical composition makes them suitable for being formed into the final product by pouring molten metal into a mold are called cast brasses, and the first digit of their designation is 8 or 9.64

7. Types of Brass

Brass basically refers to a yellowish alloy of copper and zinc, which moreover also comprise a little bit amounts of other metals, but generally 67 percent copper and 33 percent zinc. Brass has been widely used in the manufacturing of ornaments, objects or utensils and so on. As a consequence of aforesaid discussion on can conclude that brass is an only term which is used for the alloys of copper and zinc.

The strength and versatility of brass objects solely depend upon the proportions and quality of zinc and copper. While copper and zinc blended together efficiently, it gives birth to brass.65 At a world level brass has been often termed as substitution alloy.
On the bases of brass’s usage, application etc. we can categorize the types of brass as mentioned below. Following are the major Brass types:

1. **Yellow brass** is an American term for 65% Cu - 35% Zn. It is an excellent cold workability. Brass can be used for flashlight shells, lamp fixtures, radiator cores and tanks, fasteners, screws, springs, grill work, stencils, plumbing brass goods locks, hinges, plumbing accessories, pins, rivets.

2. **White brass** contains more than 50 % zinc and is too brittle for general use.

3. **Red brass** is an American term for CuZnSn alloy known as [gunmetal](#). It is an excellent cold workability, good hot formability. It can be used for weather-stripping, conduit, sockets, fasteners, fire extinguishers, condenser and heat exchanger tubing, plumbing pipe, radiator cores etc.
4. **Forging Brass** contain 59.5% Cu, 2.0% Pb, 38.0% Zn. It is an excellent hot workability. Fabricated heading and upsetting, hot heading and upsetting, machining. It can be used for forgings and pressings of all kinds.

5. **Cartridge brass** is a 70% Cu and 30% zinc brass with good cold working properties. Application is radiator cores and tanks, flashlight shells, lamp fixtures, fasteners, screws, springs, grill work, stencils, plumbing brass goods locks, hinges, ammunition components, plumbing accessories, pins, rivets.

6. **High brass**, contains 65% copper and 35% zinc, has a high tensile strength and combines excellent machinability with moderate cold workability. It is used for clock plates and nuts, clock and watch backs, gears, wheels and channel plate, bearing cages, book dies, hinges, hose couplings, keys, lock parts, lock tumblers, strike plates, templates, type characters, washers, and wear plates.

7. **Low brass** is a copper-zinc alloy containing 80% Cu - 20% zinc with a light golden color, excellent ductility, cold workability and
fabricating characteristics and is used for flexible metal hoses and metal bellows, battery caps bellows, musical instruments, clock dials, pump lines, flexible hose.

8. **Free cutting brass** containing is 61.5% Cu, 3.1% Pb, 35.4% Zn. It is an excellent machinability, fabricated by machining, rolls threading and knurling and used for gears, pinions, automatic high-speed screw machine parts.

9. **Naval brass** containing is 60.0% Cu, 39.2% Zn, 0.8% Sn. It is an excellent hot workability and hot forgeability, Fabricated by blanking, drawing, bending and upsetting, hot forging, pressing. It is application in aircraft turnbuckle barrels, balls, bolts, marine hardware, nuts, propeller shafts, rivets, valve stems, condenser plates, welding rod.

10. **Admiralty brass** contains 30% zinc and 1% tin which inhibits dezincification in most environments.
11. **Silicone red brass** contains 81.5% Cu, 14.5% Zn, 4.0% Si. It is an excellent hot formability or fabrication by forging, screw machine operations. It’s application in valve stems where corrosion resistance and high strength are critical.

12. **Alpha brasses** with less than 35% zinc, are malleable, can be worked cold, and are used in pressing, forging, or similar applications. They contain only one phase, with face-centered cubic crystal structure. Prince’s metal or Rupert’s metal is a type of alpha brass containing 75% copper and 25% zinc. Due to its beautiful yellow color, it is used as an imitation of Gold.

13. **Alpha-beta brass (Muntz metal)**, also called duplex brass, is 35–45% zinc and is suited for hot working. It contains both α and β’ phase; the β’-phase is body-centered cubic and is harder and stronger than α. Alpha-beta brasses are usually worked hot.

14. **Beta brasses**, with 45-50 % zinc content, the beta brasses are less ductile than the alpha types and generally must be hot worked or cast in order to be fabricated into useful articles. What is
Interesting is that in spite of the lower copper content the beta brasses have rather good corrosion resistance, relative to the alpha brasses. Thus beta brasses are commercially useful for marine hardware, heat exchange tubing and architectural panel sheets.

15. Aluminium brass contains 77.5% Cu, 20.5% Zn, 2.0% Al, which improves its corrosion resistance, excellent cold workability for forming and bending. Application is condenser, evaporator and heat exchanger tubing, condenser tubing plates, distiller tubing, ferrules.

16. Arsenical brass contains an addition of arsenic and frequently aluminium and is used for boiler fireboxes.

17. Manganese brass is a brass most notably used in marking golden dollar coins in the United States. It contains roughly 70% copper, 29% Zinc and 1.3% manganese with excellent cold formability, fabricated by blanking, bending, forming, stamping, welding.
18. **Common brass**, or rivet brass is a 37% Zinc brass, cheap and standard for cold working.

19. **Rich low brass** is 15% Zinc. It is often used in jewelry application.

20. **Tonval brass** is a copper-lead-zinc alloy. It is not recommended for seawater use, being susceptible to dezincification.

22. **Free-machining brasses**, typically, free-machining brass contain about 58% copper and 39% zinc. Lead is added to improve machinability. Additions of other elements such as manganese, tin, aluminium, iron, silicon and arsenic may be used to improve strength and corrosion resistance.

[Source: According to Reference No. 66]

8. **The Manufacturing Process:**

The manufacturing process used to produce brass involves combining the appropriate raw materials into a molten metal, which is allowed to solidify. The shape and properties of the solidified...
metal are then altered through a series of carefully controlled operations to produce the desired brass stock.

Brass stock is available in a variety of forms including plate, sheet, strip, foil, rod, bar, wire, and billet depending on the final application. For example, brass screws are cut from lengths of rod. The zigzag fins used in some vehicle radiators are bent from strip. Pipes and tubes are formed by extruding, or squeezing rectangular billets of hot brass through a shaped opening, called a die, to form long, hollow cylinders.

The differences between plate, sheet, strip, and foil are the overall size and thickness of the materials. Plate is a large, flat, rectangular piece of brass with a thickness greater than about 0.2 in. (5 mm)—like a piece of plywood used in building construction. Sheet usually has the same overall size as plate, but is thinner. Strip is made from sheet that has been cut into long, narrow pieces. Foil is like strip, only much thinner. Some brass foil can be as thin as 0.0005 in (0.013 mm).
The actual manufacturing process depends on the desired shape and properties of the brass stock, as well as the particular machinery and practices used in different brass plants. Here is a typical manufacturing process used to produce brass sheet and strip.

**Melting**

- The appropriate amount of suitable copper alloy scrap is weighed and transferred into an electric furnace where it is melted at about 1,920°F (1,050°C). After adjusting for the amount of zinc in the scrap alloy, an appropriate amount of zinc is added after the copper melts. A small amount of additional zinc, about 50% of the total zinc required, may be added to compensate for any zinc that vaporizes during the melting operation. If any other materials are required for the particular brass formulation, they are also added if they were not present in the copper scrap.

- The molten metal is poured into molds about 8 in x 18 in x 10 ft (20 cm x 46 cm x 3 m) and allowed to solidify into slabs called cakes. In some operations, the melting and pouring are done semi-continuously to produce very long slabs.
• When the cakes are cool enough to be moved, they are dumped out of the molds and moved to the rolling area where they are stored.

*Hot rolling*

• The cakes are placed in a furnace and are reheated until they reach the desired temperature. The temperature depends on the final shape and properties of the brass stock.

• The heated cakes are then fed through a series of opposing steel rollers which reduce the thickness of the brass step-by-step to about 0.5 in (13 mm) or less. At the same time, the width of the brass increases. This process is sometimes called breakdown rolling.

• The brass, which is now much cooler, passes through a milling machine called a scalper. This machine cuts a thin layer off the outer faces of the brass to remove any oxides which may have formed on the surfaces as a result of the hot metal’s exposure to the air.
Annealing and cold rolling

As the brass is hot rolled it gets harder and more difficult to work. It also loses its ductility, or ability to be stretched further. Before the brass can be rolled further, it must first be heated to relieve some of its hardness and make it more ductile. This process is called annealing. The annealing temperatures and times vary according to the brass composition and desired properties. Larger pieces of hot-rolled brass may be placed in a sealed furnace and annealed together in a batch. Smaller pieces may be placed on a metal belt conveyor and fed continuously through a furnace with airtight seals at each end. In either method, the atmosphere inside the furnace is filled with a neutral gas like nitrogen to prevent the brass from reacting with oxygen and forming undesirable oxides on its surface.

The annealed pieces of brass are then fed through another series of rollers to further reduce their thickness to about 0.1 in (2.5 mm). This process is called cold rolling because the temperature of the brass is much lower than the temperature during hot rolling. Cold rolling deforms the internal structure of the brass, or grain, and
increases its strength and hardness. The more the thickness is reduced, the stronger and harder the material becomes. The cold-rolling mills are designed to minimize deflection across the width of the rollers in order to produce brass sheets with near-uniform thickness.

- Steps 7 and 8 may be repeated many times to achieve the desired thickness, strength, and degree of hardness. In some plants, the pieces of brass are connected together into one long, continuous sheet and are fed through a series of annealing furnaces and rolling mills arranged in a vertical serpentine pattern.

- At this point, the wide sheets may be slit into narrower sections to produce brass strip. The strip may then be given an acid bath and rinse to clean it.

**Finish rolling**

- The sheets may be given a final cold rolling to tighten the tolerances on the thickness or to produce a very smooth surface finish. They are then cut to size, stacked or coiled depending on
their thickness and intended use, and sent to the warehouse for distribution.

- The strip may also be given a final finish rolling before it is cut to length, coiled, and sent to the warehouse.

**Quality Control**

During production, brass is subject to constant evaluation and control of the materials and processes used to form specific brass stock. The chemical compositions of the raw materials are checked and adjusted before melting. The heating and cooling times and temperatures are specified and monitored. The thickness of the sheet and strip are measured at each step. Finally, samples of the finished product are tested for hardness, strength, dimensions, and other factors to ensure they meet the required specifications.
9. FEATURE OF BRASS

Brass has a combination of strength, corrosion resistance, and formability that will continue to make it a useful material for many applications in the foreseeable future.\textsuperscript{68} Brass also has an advantage over other materials in that most products made from brass are recycled or reused, rather than being discarded in a landfill, which will help ensure a continued supply for many years.\textsuperscript{69}

Due to the capability of brass of being converted into different designs and shapes and its acoustic properties, brass has become one of the preferred item to be used in numerous applications.

There are many feature of brass as under:

1. **Excellent Machinability:**
   
   Machined components can be cheaper in brass than in mild steel.
   
   - All brasses are intrinsically easy to machine
• The addition of small amounts of lead to brasses further improves this property and slight reduction in ductility when lead is present
• 'Free machining brass' sets the standard by which other materials are judged when machinability is being assessed
• Higher machining speeds and lower rates of tool wear mean the overall production costs are minimized
• Tolerances are held during long production runs and surface finish is excellent.

2. Good Strength:
• In the softened or annealed condition, the brasses are ductile and strong but when hardened by cold working techniques such as rolling or drawing, their strength increases markedly. Strong, stiff structures can be assembled from extruded-and-drawn sections. Bars and rolled sheet and plate can be fabricated into containers and other items of plant which work under pressure
• The strength of brasses is substantially retained at temperatures up to around 200°C and reduces by only about 30% at 300°C which compares favorably with many alternative materials.

• The brasses are very suitable for use at cryogenic temperatures since the properties are retained or slightly improved under these operating conditions.

• For applications demanding higher strengths the "high tensile brasses" are available. These contain additional alloying elements which further improve the properties.⁷⁰

3. Ductility:

• Brasses with a copper content greater than 63% can be extensively deformed at room temperature, and are widely used for the manufacture of complex components by pressing, deep drawing, spinning and other cold forming processes.

• If the copper content is below 63% and no other alloying elements are present, the room temperature ductility is reduced, but such alloys can be extensively hot worked by rolling, extrusion, forging and stamping.
• Strength, ductility and formability are retained at low temperatures, making the alloys ideal for cryogenic applications.

4. Conductivity:
• Brasses have good electrical and thermal conductivities and are markedly superior in this respect to ferrous alloys, nickel-based alloys and titanium.
• Their relatively high conductivity, combined with corrosion resistance, makes them an ideal choice for the manufacture of electrical equipment, both domestic and industrial.
• Condenser and heat exchanger tubing also require the good thermal conductivity of copper and its alloys.

5. Easily Joining:
Brasses may readily be joined to other copper alloys or to other metals by most of the commercial joining processes such as:
• Riveting
• Soft soldering
• Brazing
• Friction welding
• Modern adhesive joining practice

6. **Non-sparking:**

Brasses do not spark when struck and are approved for use in hazardous environments.

7. **Good Corrosion Resistance:**

Brasses have excellent resistance to corrosion that makes them a natural, economic first choice for many applications.

- Atmospheric exposure of the brasses results in the formation of a thin protective green "patina", a visually attractive feature in buildings.
- Brass will remain essentially unaffected for an unlimited period of time, i.e. it will not rust away like iron and steel.
- Seawater can be handled successfully providing the correct alloy is chosen, and there is a long history of the use of brass tube and tube fittings, valves, etc. in domestic plumbing, central heating, seawater lines, steam condensers and desalination plant.
• High tensile brasses containing manganese have particularly excellent resistance to atmospheric corrosion, continual exposure resulting in a gradual darkening of the bronze colour.\textsuperscript{71}

8. Wear Resistant:

The presence of lead in brass has a lubricating effect that gives good low friction and low wear properties utilized in the plates, pinions and gears used in instruments and clocks.

Special brasses are available with additions of silicon that make the material ideal for use in heavy duty bearings.\textsuperscript{72}

9. Plating:

• Brasses may be polished to a high surface finish which can then be either easily repolished when required or lacquered to preserve the natural colour, enamelled or plated with chromium, nickel, tin, silver, gold, etc. as required. Alternatively, the surface can be toned to a range of colours, from "bronze" through various shades of brown, to blue-black and black, using
commercially available toning chemicals. These coloured finishes are frequently used for decorative and architectural metalwork.

- All types of common plating processes may be used. For many other metals it is usual to use a copper plate underlayer. This is not required on brass because it is easily polished and does not need the expense of an initial copper strike. To give extra corrosion protection to steel when used against brass, cadmium plating of the brass was traditional but this has now been generally replaced by zinc.\(^7^3\)

10. **Attractive Colour:**

Brasses are extensively used for durable decorative applications and for the manufacture of functional items where aesthetic appeal is a requirement in addition to a long service life.

- In brasses, the red of copper is toned to a range of attractive yellow hues by the addition of varying amounts of zinc ranging from the gold-like colours of the 95/5, 90/10, 85/15 and 80/20 alloys (appropriately called "gilding metals") through the more
subtle variations in the 70/30, 2/1 and 64/36 series of brasses to the stronger yellow colour of the 60/40 alloy, formerly known as "yellow metal".

- Aluminium brasses have a distinctive silvery sheen.
- The addition of manganese to certain brasses gives them an attractive bronze colour when extruded.
- High tensile brasses, some of which are otherwise known as "manganese brasses" or previously "manganese bronzes" are particularly suitable for architectural applications since they can also be patinated to a range of durable brown and bronze finishes. 74

11. Hygiene:

Copper is well known as a biocide and the copper content of the brasses has the beneficial effect of restricting the growth of microorganisms. Test on door hardware such as knobs and kick plates have shown that those that are made of brass are far less likely to encourage the growth of the organisms causing nosocomal infections than other materials. Brass fittings, free from further
protective finishes, should therefore be used in sensitive environments such as hospitals.75

12. Magnetic permeability:

Brasses are essentially non-magnetic, a property which has gained them extensive use in electrical and electronic equipment, as well as instrumentation such as geological and survey equipment.76

13. Castability:

All brasses can be readily cast for a wide variety of end users giving strong, sound castings. The old BS1400 and the new BS EN specification cover a selection of the most frequently used alloys, some with additions of lead to improve machinability, and tin to improve corrosion resistance and strength. Manganese is a useful deoxidant, as little as 0.02% present giving stronger, sound castings. For die-casting the 60/40 type alloys are used.77 The higher zinc content lowers the casting temperature and gives essential hot ductility. Aluminium is added to form a protective oxide film to keep the molten metal clean and reduce the attack on the die materials. This type of alloy with a suitably controlled
composition may also be used for castings required to be resistant to dezincification.\textsuperscript{78}

The casting process is ideal for the production of complex shapes. End users range from pipeline valves and electrical switchgear components which require high soundness and strength, a long operating life and, in the case of components for mines and the petrochemical industry, spark-resistant characteristics, to non-critical ornamental applications where the requirement is for a good surface finish as well as a long service life.\textsuperscript{79}

14. Available Forms and Properties:

Being easily shaped by hot and cold working processes, the brasses are manufactured in a wide variety of forms. Semi fabricated stock is available as rolled plate, sheet, strip and foil and as extruded and drawn bars, shaped sections, hollow rods, tubes and wire. Intermediate products can be obtained as hot stampings, forgings, sand castings, shell moulded castings, gravity and pressure diecastings, and investment castings. The availability of these
items to specific composition and size specifications may be dependent on quantity requirements. Dimensional tolerances suitable for most general engineering applications are quoted in the relevant British Standards for the wrought products. Any special requirements should be discussed with manufacturers.

15. Cost effectiveness:

There are many factors, sometimes overlooked, that contribute to low costs of brass components.

- Close tolerance manufacturing techniques can be employed so that finishing costs are minimal.
- Tooling costs may be significantly lower than for other materials or processes.
- Ease of machining means that production costs can be minimized.
- The good corrosion resistance of the brasses means that the cost of protective finishing is lower than for many other materials.
In addition to these benefits the high value of any process scrap can be used to reduce production costs significantly.

In India the brass metal industry are located in three states namely Gujarat, Haryana, Orissa, Assam and Uttar Pradesh. But there is a subtle difference between the products manufactured in these three states. The products manufactured in Haryana, Orissa, Assam & Uttar Pradesh are mostly brass metal handicrafts and utility items made out of sheet metal components or single piece casting whereas in Gujarat it is mostly brass machined components. From the point of view of its application or usage pattern, the products manufactured in Uttar Pradesh, Orissa, Assam & Haryana are consumer products and are used as gift, utility or decorative items. Whereas the products manufactured in Gujarat can be classified as industrial product and consumed by industries as a part/ component of their final product. Unlike the above four states, the brass part product in Gujarat requires a lot of machining activities like turning, milling, grinding, drawing, boring, threading etc.
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