Introduction to Ancient Indian Technology.
Professor D. P. Mishra.
Department of Aerospace Engineering.
Indian Institute of Technology, Kanpur.
Lecture-38.

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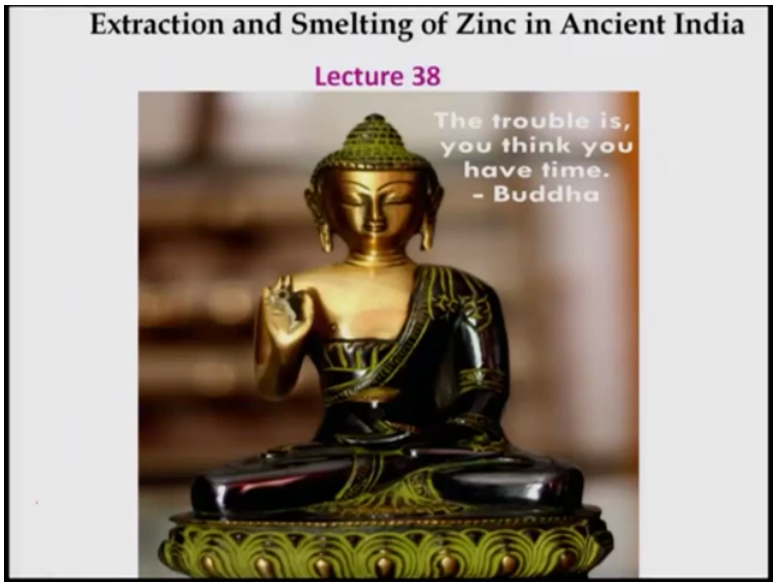

We will start this lecture with a thought process from Lord Buddha whose image I have shown here which happens to be, a nonferrous metal. He says that trouble is you think you have time. Today we will be basically discussing about extraction and smelting of Zinc in ancient India and I have chosen this because it is considered to be the, you know first unravel in our country in ancient time.

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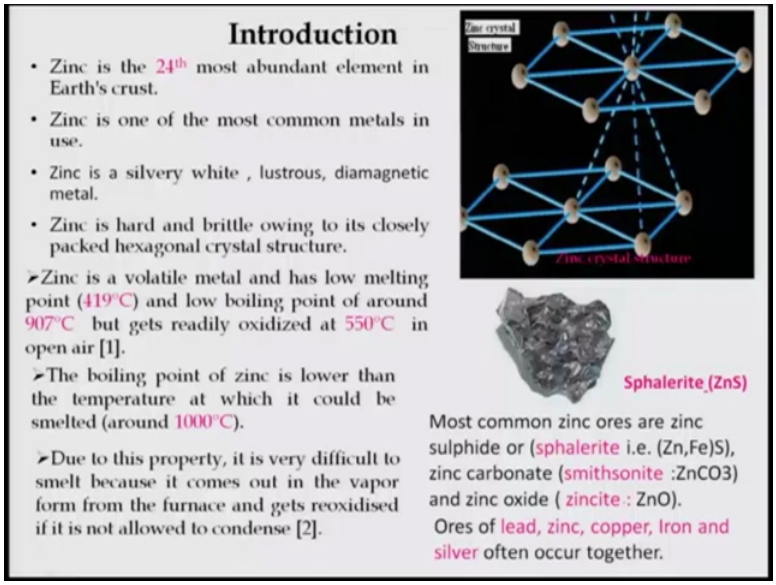

And, so you must be knowing that zinc is the 24th most abundant element in earth's crust. As a result zinc is one of the most common metal in use after iron, copper and aluminium. This is the fourth metal which is used plentily and you might be knowing that you know, like we use galvanised iron, to avoid the rusting on it and basically that is zinc is being coated on that. And zinc is a silvery white lustrous diamagnetic metal and zinc is hard at the same time brittle due to its closely packed hexagonal crystal structure.

If you look at the crystal structures I have shown here, this is hexagonal and its quite packed as a result you know you will get these properties and zinc is a volatile metal, and it has a low melting point around 419.5 degree Celsius. Of course I have written 419 just to make you to remember and low boiling point around 907 degree Celsius, but gets readily oxidised around 550 degree Celsius in open air. As a result it is very difficult to smelt as compared to iron because of fact that the boiling point of the zinc is lower than the temperature at which it could be smelted around 1000 degree Celsius.

And as soon as it will come in contact particularly the zinc vapour with the air, it will get oxidised and therefor it is very difficult to smelt, as compared to any other metal. So most of the common zinc ores in India and others, other places also, like zinc sulphite, what is being also known as Spalarite. Here I have shown a figure that which is basically ore and is having some structures and where it is, you know some zinc will be there and of course in this Spalarite you may find iron also in that, Zinc carbonate and zinc oxide generally zinc oxide is not available in you know, plentily, but however the zinc sulphite is converted into zinc oxide then you can get the zinc metal out of it. The ores of lead, zinc, copper iron and silver often

occur together along with the zinc, therefore one has to be very carefully handle this kind of metal.

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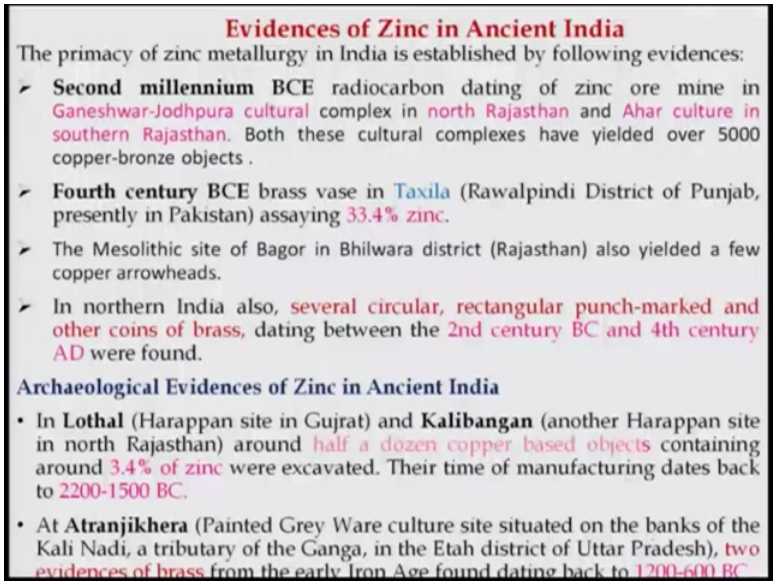

So if you look at the application of zinc metal in modern time it is quite enormous. Let me just give you overall pictures like you know application wise as I told the construction we use the zinc in ship building industries, household electrical applications, batteries you know like and then production of alloys like brass, and then you know other metals being used, galvanising the, to protect the steel, as I told earlier, as a chemical additives in rubber and paints and in automobile of course we use this plentily.

And of course there are several other applications which I have not included here, but zinc is being used very much and it is being produced plentily. So let us look at now, what are the evidence of zinc being you know, mined and smelted in ancient India, some of these evidences we will be discussing, because of due to paucity of time. And if you look at the evidence, being obtained particularly from Ganeshwar Jodhpura cultural complex North Rajasthan and Ahar culture in southern Rajasthan and these are basically what you call people obtained from there area around 5000 copper bronze objects and they have carried out ready carbon dating and it amounts to be that, these products basically belong to second millennium BC, that has been you know, checked.

And besides these, 4th century BCE people got brass vase in Taxila which happens to be now Rawalpindi district of Pak, Punjab in Pakistan and which contains something around 33.4 percent zinc. And Mesolithic site of Bagor, in Bhilwara district of Rajasthan also yielded a

few copper arrowheads and of course it will be containing some amount of zinc, you can call it basically as brass arrowheads.

And in northern India also several circular rectangular punch marked and other coins of brass dating between something 200 BC to 4th century AD were found out. If you look at there is more archaeological evidence of zinc in ancient India, it goes to the Harappan site like Lothal and then Kalibangan, another one site in northern Rajasthan. And they found around half a dozen copper based objects contain zinc around 3.4 percentage . Might be this copper will be having this what you call, impurities zinc, whether they have added or not is one question generally comes over, but the time of manufacturing date backs to something 2200 to 1500 BC.

And there is another site where people got what you call, two evidences of brass, which is from early Iron Age dating back to around 1200 to 600 BC and this site you are very much aware. This is a Atranjikhera site which is near the river kali nadi banks, a tributary of Ganga in Etah district of utter Pradesh.

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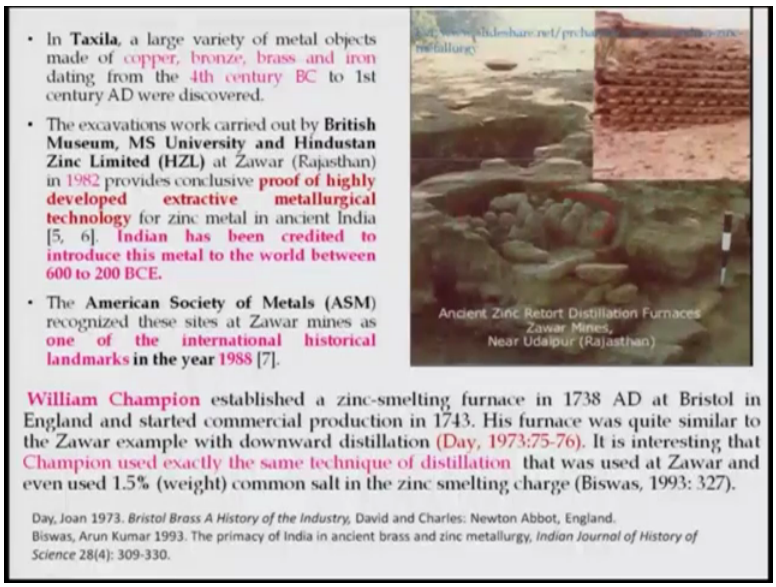

So as I told earlier in Taxila large varieties of metal objects made of copper, bronze, brass, iron dating back to 400 BC to the 100 AD were found out. And excavation work carried Ou by the Birth museum and MS University of Baroda and Hindustan Zinc Limited at Zawar, Rajasthan around 1982 provides a very conclusive proof of highly developed extractive metallurgy technology for zinc metal in ancient India. And if you look at they have also

concluded that the Indians should be credited to the, to introduce this metal to the world between 600 to 200 BC.

Because actually they did a very extensive study jointly and then unravelled, as a result later you know this around 1988, American Society of Metals recognised these sites at Zawar mines as one of the international historical land mines for the zinc because of this research. And I am just showing some of the things what they got during this research. This is a ancient zinc retort distillation, they are saying this is the furnace and these are the some you know kind of things.

And we will be discussing more about this, zinc distillation method which is being you know they found several of them and these are the (())(10:00) which are being you know used for the making a house, you know, these are being layered by layer, they used it as a brick in some places, they found at that time. And this is near Udaipur of Rajasthan, that means lot of production of this zinc might be going on. Let me tell you another very interesting fact which has been quoted in various literature I have taken. That is William Champion established zinc melting furnace in 1738 Ad at Bristol in England and started commercial production around 1743.

And according to this day, you know, the furnace was quite similar to the Zawar example with downward distillation and it is interesting that the Champion used exactly the same technique of distillation that was used at Zawar, and even used 1.5 percent of common salt in zinc smelting charge as mentioned in this Biswas paper, I have given the, that is Joan day 1973 which is talking about Bristol brass a history of industry. And it might be happened as claimed by the various authors that Britishers had learned this thing from India as they were ruling this place and they might have replicated the tech you know this thing in their place in 1738, because this zinc production was continuing even till Britishers landed in this place and maybe after that.

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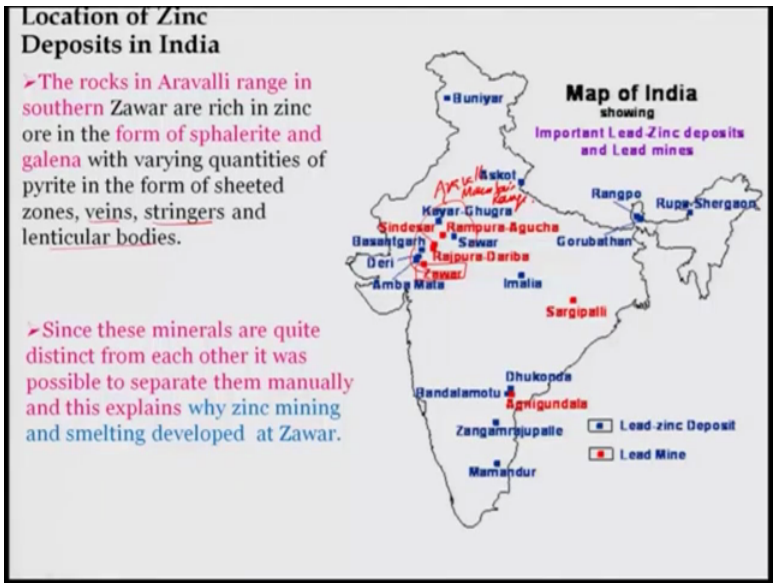

And let us look at the locations of Zinc deposits in India and these are the places lead and zinc deposits are there. If you look at this is the Zawar region where the lead mines, of course are there, and 25 km from that you know, these are all places, Deri, Amba mata and there are several places, of course the other places are there, in other parts of the country. The rock in, this region is Aravalli region right, Aravalli mountain range. The rocks in Aravalli range in the southern Zawar are rich in zinc ore in the form of Spalarite and galena.

These two ores we had discussed earlier with varying quantities of pyrates in the form of sheeted zoned and there might be veins, and stingers of course the lenticular bodies kind of things, where the zinc will be there in between. And since this material are quite distinct from each other it might be possible at that time to separate them manually and that I the reason why zinc mining and smelting you know was developed at Zawar region, right, that is what people are anticipating.

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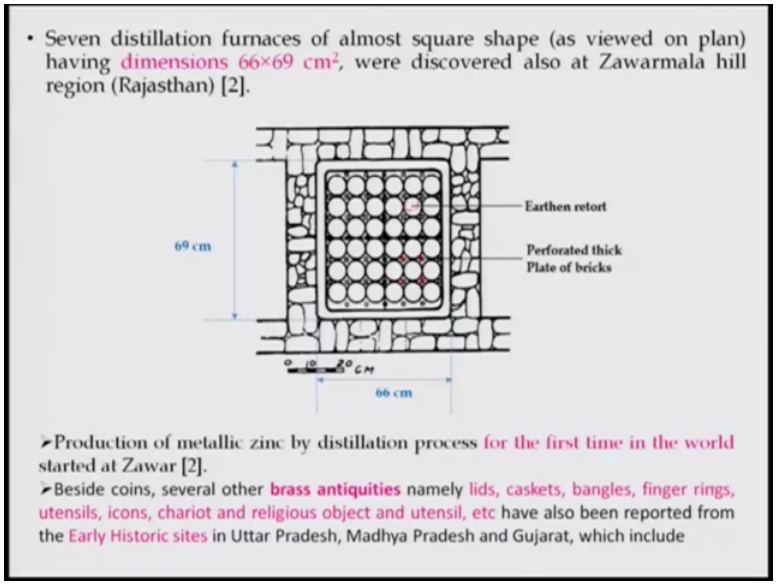

And 7 distillation furnace of almost square shape, we will see its image like having a dimension like this is 69 centimetre and this is 16 centimetre were discovered in Zawarmala hill region. And these are the earthen retort place where it will be placed and there is also, the perforated, these are some holes are there here in this region were you know, being made for the air passage and also the ores to be coming down to the furnace. We will be discussing more about it. And the production of metallic zinc by the distillation process was started at Zawar for the first time in the world as claimed by various people.

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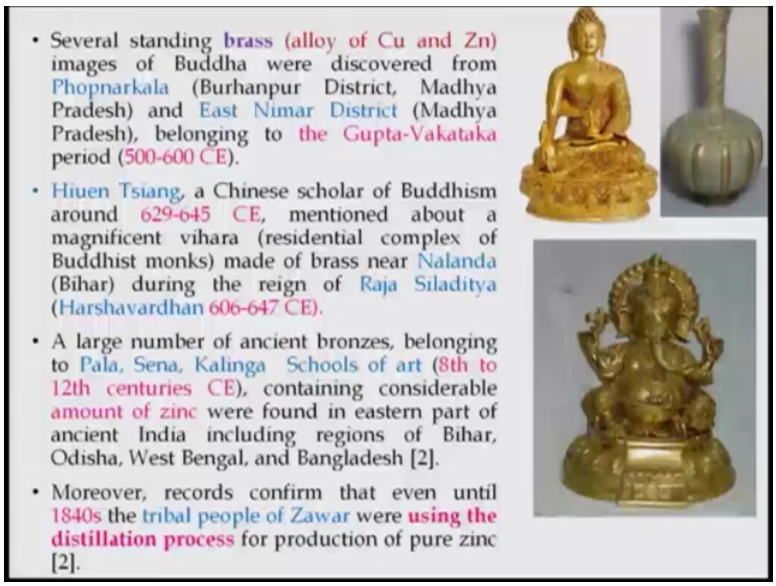

Besides coins several other brass antiquities namely lids, caskets, bangles, finger ringa, utensils, icons, chariots, religious objects, utensils have also being found from early historic

sites in Utter Pradesh, Madhya Pradesh, Gujarat. Several brass images of Buddha were discovered from Phopnarkala of Burhanapur district of MP and east Nimar district of MP belonging to Gupta and Vakataka period, something around 500 to 600 CE.

Hiuen Tsiang a Chinese scholar of Buddhism around 629 to 445 CE mentioned about Buddha statue in a magnificent Vihara near Nalanda during the reign of Harshavardhan 606 to 647 CE and this statue is made of brass as it was mentioned in his travelogue. A large number of ancient bronze belonging to Pala, Sena, and Kalinga School of art around something 800 to 1200 CE, contains considerable amount of zinc which were found in the eastern part of ancient India including the region of Bihar Odisha, west Bengal and Bangladesh.

And moreover records confirm that even until 1840 the tribal people of Zawar were using the distillation process for the production of pure zinc and that clearly indicates that you know Britishers might have learned this thing from the tribal people of Zawar region about the distillation process of zinc smelting. And this is of course about the archaeological evidence, but there are several literary evidences of the zinc in ancient India.

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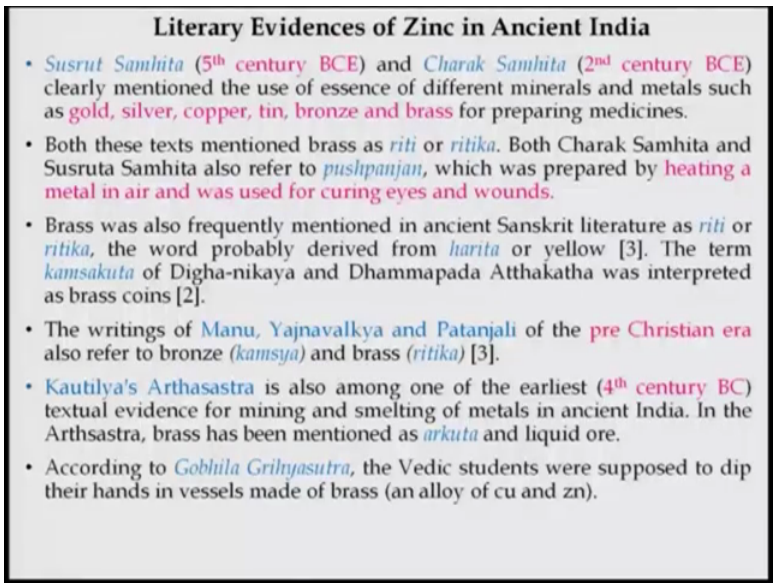

One can think of Susrut Samhita, and Charak Samhita which clearly mentioned the use of essence of different minerals and metals such as gold, silver, copper, tin, bronze and brass for preparing the medicines. Of course we have discussed some of them. But we are not talking about brass which contains zinc, and both these texts mention that brass has a ‘riti’ or ‘ritika’ and also they refer this to the pushpanjan which was prepared by heating a metal in air and was used for curing eyes and wounds. That means this brass can be done that job.

And brass was aslo frequently mentioned in Sanskrit literature as riti or ritika the word probably derived from the Harita or yellow colour because brass being yellow in colour. The term Kamsakuta or Digha nayaka or Dhamma pada or Atthakatha was interpreted as brass coins. Besides these writings of Manu, Yajnavalkya and Pathanjali of the pre- Christian era also refer to the bronze as kansa and brass as ritika. And Kautilya's Artha sastra also one of the earliest textual evidence of mining and smelting of metal in ancient India. In the Artha sastra brass has been mentioned as arkuta and liquid ore. According to the Gobhila Grihyasutra, the Vedic students were supposed to dip their hands in vessel made of brass an alloy of copper and zinc.

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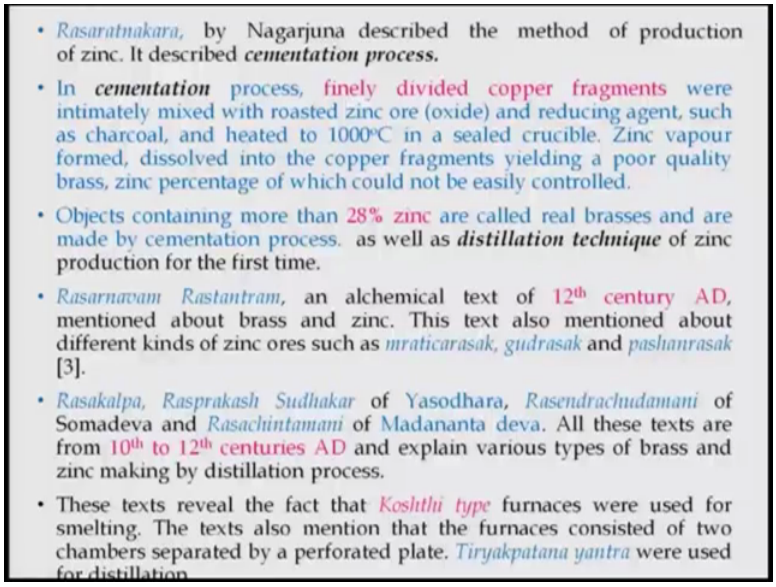

Rasaatnakara by Nagarjuna describe the method of production of Zinc. And if you look at, about the dates when it was, there is a little controversy. But however one can see very clearly in that book, that it has described about a cementation process of making zinc. And in this cementation process the finely divided copper fragments were intimately mixed with the roasted zinc ore and reducing agents such as charcoal, and heated up to the temperature around 1000 degree Celsius in a sealed crucible. And the zinc vapour formed dissolve into the copper regents yielding a poor quality brass. And unfortunately by this method the zinc percentage can be easily controlled.

But they produce this brass in a small quantities because for the medicinal purposes. And objet containing more than 28 percent zinc are called real brasses are made by cementation process as well as the distillation technique of the zinc production for the first time. Besides these there are several alchemical text as mentioned about the use of brass and zinc and these

texts also mention about different kinds of zinc ores such as mraticarasak, gudrasak and pashanrasak. And Rasakalpa and Rasaprakasha Sudhakar of Yasodhara and Rasendrachudamani of the Somadeva, Rasachinthamani of Madanta deva are being you know, were being written something around 10 to 12 century AD explains various types of brass and zinc making by distillation processes.

And these texts reveal the fact that Koshthi type of furnace were used for smelting and the text aslo mention that furnace consists of two chamber repeatable by a perforated plate and Tiryakpatana Yantra were used for distillation. If you look at there is lot of literary evidence for zinc distillation technique and also the cementation process for making zinc.

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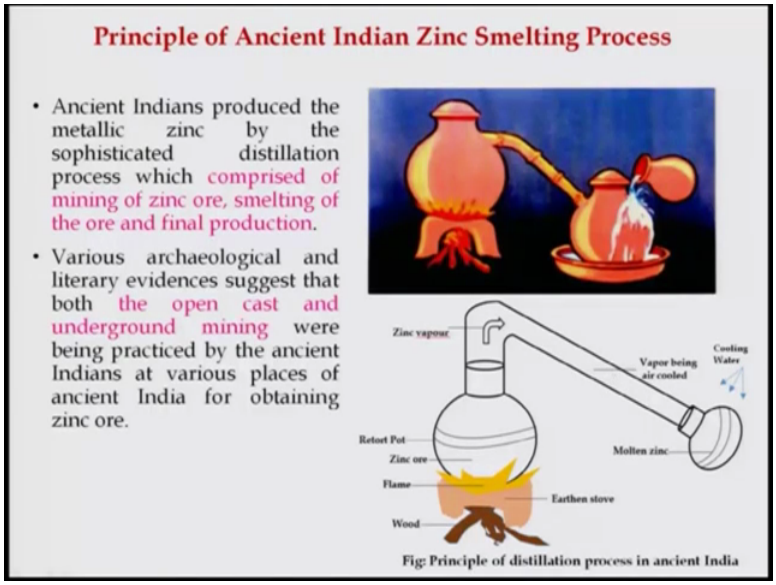

Let us look at what is the basic principles being used for smelting the zinc in ancient time and generally it is being produced by the sophisticated distillation process which comprise of mining of zinc ore, and smelting of ore and of course the final product. Various archaeological and literary evidence what we have seen just now, suggest that both the open cast and underground mining were being practiced by the ancient Indians at various places for obtaining the zinc ore. And this is the diagram which I am showing, particularly a distillation process.

If you look at this is the container where you can take the liquid and heat it, the vapour will be formed and then you will take this vapour out in this tube and you cool with the help of water or air cooling so that it will be condensed back. And this process is basically being used for zinc production, that means the zinc ore is taken here and then it will be heated with the

help of, of course flame produced by due to the burning of wood and of course I mean which is shown here but in actual situation charcoal is being used in that retort.

There it will be, the zinc will be vaporised and then it will pass through this tuyeres or the pipe which will be can be condensed by with the help of cooling it and also vapour being air cooled in this pipe if it is made of metal.

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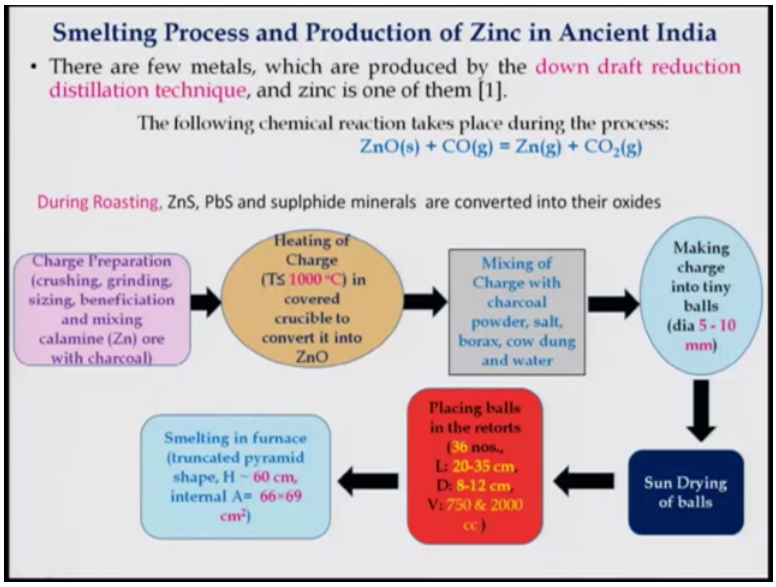

So let us look at the smelting process and production of zinc in ancient India and as I had mentioned earlier there are few metals which are produced by the down draft reduction distillation technique and zinc is one of them because of its boiling point is very low. And what is being done in this case is that, the charge is prepared. Of course for preparing charge the ore has to be crushed, grinded and to a proper size and beneficiation will be taken place and then you will have to make these things, you know, Calamine or the ink or with the charcoal.

And then you will be putting into a crucible and covered it and heat it may be around 1000 degree Celsius. As I had told you earlier, that zinc sulphite and lead sulphite, sometimes they together this sulphite minerals are converted into their oxides, right. And once these oxides, zinc oxide is being produced then you will have to separate it out. And then this zinc oxide mix will be again the charge will be produced, will be prepared by mixing this zinc oxide with charcoal powder. Of course the wood, charcoal and then salt, borax and then you will have to use cow dung and water so that it will be binded properly and then you will have to make some kind of pellets of ball size around 5 to 10 mm and these pellets are to be sun

dried, and these ball shaped pellets are being put into a retort of length around 20 to 30 centimetres, diameter 8 to 12 centimetres.

Of course its volume two volumes were being used in ancient times, one is 750 CC other was a little larger, or later more than double that is 2000 CC. And then of course one it will be placed and then it will be, it will put into smelting furnace which I will be showing little, which is of truncated pyramid shape and then it will be heated to a little higher temperature. As a result that zinc oxide will be reacting with the CO which is produced by this charcoal, right and then zinc will be produced and also the carbon dioxide it will be in the vapour state, zinc and then you will have to condense it to get the zinc metal.

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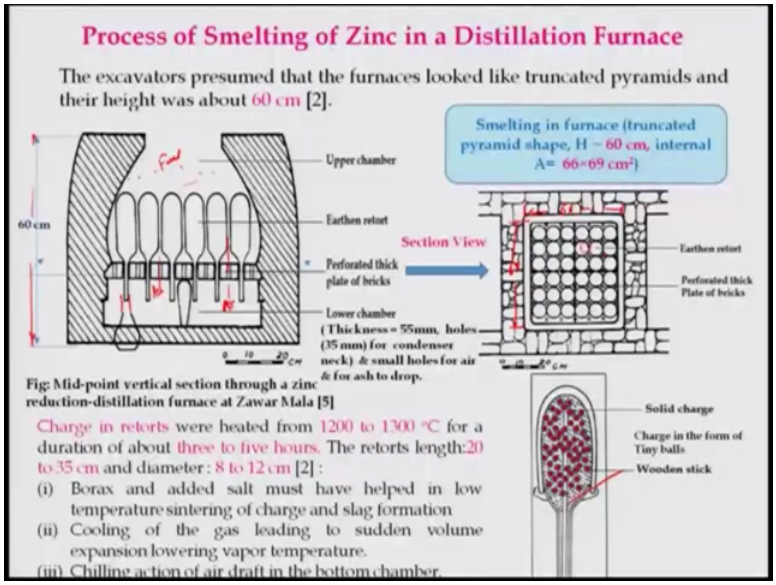

So this is the what you call, a vertical section of a zinc reduction furnace which was obtained at Zawar Mala and this if you look at, it is basically a truncated pyramid shape and its height is 60 centimetres. If you look at from here, to this thing is 60 centimetres. And these are the earthen retorts which are placed in this and this will be the sectional view if you take it will be shown here this perforated thick plate of bricks right, and which will be holding these earthen retorts and in this place these are the earthen retorts. And these are small holes which will be there to for the air to pass through and as I told that this is the furnace is having 69 centimetres, this is basically 69 centimetres and this is your 66 centimetres cross section.

And the charge in retort were heated around to 1200 to 1300 degree Celsius for a duration about 3 to 5 hours. And retorts have the length of around 20 to 35 centimetres diameter of course 8 to 12 centimetres kind of things. And generally what happens like here the fuel

being placed and it will be burned so that heat will be soaked into this region. And then this of course there is a lower chamber, the peg is there which is being what you call support this brick and there is a container which is being displaced a little bit and this container is being placed where once this is being melted vapour being produced and then it will be coming out.

Let me show you the retort and this retort will be containing a small pellets of spirical size together and it will be packed in this brinjal shaped retort and with a wooden stick in between. This wooden stick right, this is your wooden stick and which will help to support these things so that it will not fall due to gravity. But another interesting thought once it is heated to the 600 around degrees this will be also having some carbon and giving the reducing agent some carbon dioxide will form. And also it will create a passage for the vapour to come out and collect in this vessel, right, lower chamber vessel.

And the, as I told the borax and the added salt must have been helped in low temperature sintering of charge and slag that will be and cooling of gas leading to the sudden volume expansion and lowering the vapour temperature and the chilling action of air draft in the bottom chamber might have occurred due to this sudden volume expansion kind of things. As a result and this, through this passages you know, like your ash and other things will be coming and also some air will be moving into that, what you call air for the combustion of this (())(29:19) which will be in this place.

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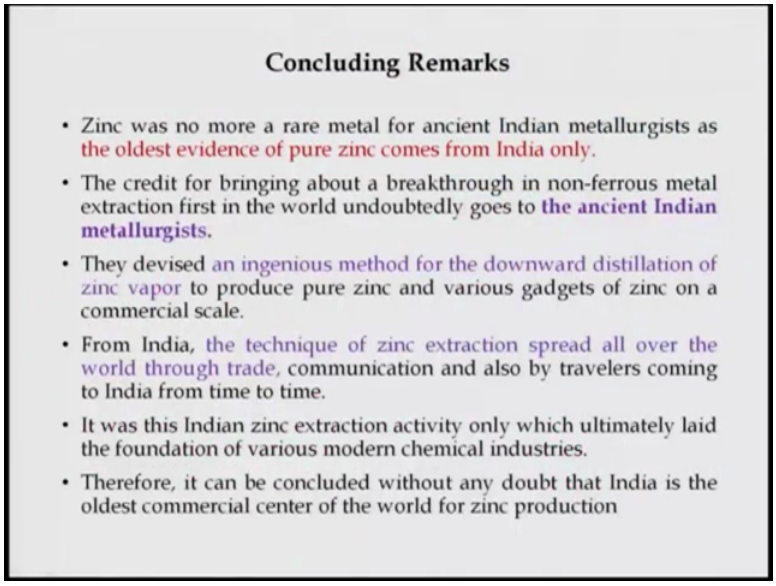

So this is a beautiful system what they had devised for producing zinc out of the metal and let me conclude that zinc was no more a rare metal for ancient Indian metallurgist, as the oldest

evidence of pure zinc comes from India only. It has been accepted by the researchers and the credit for bringing about a breakthrough in nonferrous metal extraction first in the world undoubtfully goes to the ancient Indian metallurgists. They devised an indigenous method for downward distillation of zinc vapour to produce zinc and various gadgets of zinc on a commercial scale. And from India the technique of zinc extraction might have spread all over the world through trade and communication, also by travellers coming to India from time to time.

Of course this is a very clear evidence which has been discussed earlier that Britishers might have learned from us, what they produce in Bristol. And therefore it can be concluded without any doubt, India is the oldest commercial center in the world for zinc production. And thank you very much for listening this talk then we will be discussing more about how to make a what you call bronze idols out of this metal in the next lecture thank you very much.