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DESIGN AND ERECTION OF COPPER PLANTS TAKING INTO ACCOUNT THEIR FUTURE EXPANSION [1]

by

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

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SUMMARY

The rapid increase in the demand for copper is accompanied by increasing copper production. During the last seven years the world's production of refined copper increased by 46 per cent. In connexion with the demand and the high price of copper, new deposits of copper ore are being discovered and exploited, and the erection of new copper smelters is being prepared.

Selection of the main method of processing copper-bearing raw materials

Reverberatory furnaces. Raw materials for this method are copper concentrates of a sulphur content equal at least to that of copper; they, however, may not be high-melting. The concentrates to be processed by this method may be pre-dried only. Improved reverberatory furnaces of large sizes and fired with cheap fuel (natural gas or oil) are inexpensive to use.

Blast furnaces. Raw materials for this method are rich lumped ores containing more than 5 per cent of copper or briquetted or pelletized copper concentrate which for various reasons, due to low bitumen content, cannot be smelted by other methods. Concentrates containing more sulphur can be lumped by sintering, but this is an expensive process. It is an easy method, smelting in blast furnaces, and this smelting method can be adapted to smaller production volumes. Coke is indispensable for this method.

Resistance arc furnaces. Raw materials for this method can be high-melting concentrates. It is desirable that they should contain a sufficient amount of sulphur in order that they can be pre-roasted without heat supply and, when still hot, they can directly be smelted in electric furnaces in order to increase the output of these furnaces and to decrease power consumption. Electric furnaces may be used only when cheap electric power is available, generated by water force, gas or brown coal.

Flash smelting furnaces. Raw materials for this method are sulphur-rich copper concentrates dried down to a water content of 0.5 per cent in order that the process employed for their smelting should be autogenous. The amount of volatile accompanying metals (Zn, Pb) and volatile rare metals (Ge, Re) driven off is very high and can be used for smelting these concentrates which contain these elements. The gas escaping from flash smelting furnaces contains much sulphur dioxide and can be processed to sulphuric acid or liquid sulphur dioxide. Flash smelting furnaces must be fully automatized, otherwise they can hardly be run.

Hydro-metallurgical methods. Raw materials for the acidic version of the hydro-metallurgical method are oxidized copper ores of acidic deposit. Raw materials for the alkaline version (pressure ammonia leaching) of the hydro-metallurgical method are oxidized copper ores of alkaline deposit. A copper smelter employing the acidic pressureless hydro-metallurgical method is cheap; however, more expensive is a copper smelter employing the alkaline pressure hydro-metallurgical method, since autoclaves are expensive.

Bacteriological recovery methods are used for poor sulphide or sulphide-oxide ores, and to recover copper from slag. These methods are in the development stage only and are used as supplementary methods in copper ore mines for poor ores and copper smelters to recover copper from slags. Raw materials for this method must absolutely contain iron and sulphur in addition to copper, the two former elements being transformed by bacteria.

<u>Size of copper smelters</u>. The following table shows the range of the annual production volumes attainable with one furnace by individual methods; the lower figures denoting the minimum annual production volume for the given furnace type, ensuring the indispensable minimum profitability of a copper smelter and the upper figures denoting the maximum annual production volume attainable with one furnace for individual methods.

<u>Specification of the annual copper production volumes attainable and recommended for individual metallurgical methods employing one furnace</u>

Method	Version of method	Type of raw material	Annual copper production volume per one furnace (in tons)
Reverberatory furnaces	Improved	Pre-dried concentrate	40,000 - 80,000
Blast furnaces	Improved	Briquetted or pelletised concentrate	25,000 - 50,000
Flash smelting furnaces	Outokumpu	Concentrates dried down to 0.5% water content	30,000 - 50,000
	Inco	Concentrates dried down to 0.5% water content	80,000
Resistance furnace	Conventional	Pre-roasted concentrates	25,000 - 50,000

The annual copper production volumes attainable in the majority of hydro-metallurgical smelters are within 10,000 - 30,000 tons. Two hydro-metallurgical smelters only, in Chuquicamata, Chile and in Kolvezi, Africa, show considerably higher annual copper production volumes.

Selection of the building site for a copper smelter

The points which should be considered in selecting the building site for a copper smelter are as follows

(a) Copper smelters processing copper ores directly without their enrichment should be located close to respective mines;

(b) Copper smelters far away from enrichment plants and processing concentrates should obtain the latter preferably by water, by rail or in the form of a pulp by pipelines;

(c) Supply of cheap fuel, electric power, water, fluxes and refractory materials to the building site;

(d) Disposal of sulphuric acid receivers close to a copper smelter;

(e) Building site for a copper smelter shall be away from fertile soil or woods;

(f) Ground shall be fairly level, a hill on the site or close by is desirable to erect a chimney thereon;

(g) Ground of the building site shall be strong enough to avoid deep foundations;

(h) Location of a copper smelter not far from a town is desirable;

(i) Building site shall be sufficiently large to enable future extension.

Main problems to be taken into account in designing the first stage of erection of a copper smelter in order to facilitate future extension

(a) Selection of a sufficiently large building site to enable future extension;

(b) Possible construction, even in the first stage, of pipelines for gas, water and fuel oil, having throughputs sufficient for the first and second stages;

(c) Provision, in the first stage, of channels of sufficient cross section for laying additional pipelines in the second stage, should a different method of pipe laying be employed;

(d) Provision, in the first stage, of foundations for larger converters (sufficient for both the stages) and installation of smaller converters thereon in the first stage;

(e) Erection of many items of equipment outdoors or in open sheds (in warm and hot climates) to facilitate the erection close by of additional identical items in the second stage;

(f) Installation of two waste-heat boilers for one reverberatory furnace in the first stage in such a way that, after one reverberatory furnace and one waste-heat boiler have been additionally erected in the second stage, one of the waste-heat boilers erected in the first stage can be used as a stand-by unit for both the reverberatory furnaces;

(g) Stationary refining anode furnaces and stationary cathode copper melting furnaces shall be designed and erected in the first stage so that they can be extended in the second stage to any required capacity;

(h) Erection, in the first stage, of a chimney of a height and throughput required for both the stages since, after a copper smelter has been doubled, the gas from the entire copper smelter should be released at a considerably greater height than in the first stage;

(i) It is necessary for many reasons to employ as far as possible the same processing method in both the erection stages of a copper smelter method of smelting concentrates to copper matte.

General Remarks

Some building changes proposed above increase somewhat investment outlays for the first erection stage of a copper smelter and, consequently, they should be considered and fixed depending upon the time interval between the first and second erection stages.

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Introduction

1. The world's production of refined copper increases rapidly; within the last seven years the production increased from 4,273,200 tons in 1959 to 6,251,300 tons in 1966, the increase being 46 per cent. If it were taken into account that every year about 40 per cent of the production of refined copper comes from scrap, slags and other secondary raw materials, the copper production from primary raw materials was 2,564,000 tons in 1959 and 3,570,000 tons in 1966.

2. To cope with the increasing copper production from primary raw materials, also the output of copper ore of course increased, being 3,693,200 tons of copper in the ore for 1959 and 5,288,000 tons of copper in the ore for 1966. In view of the high demand for copper both with regard to its consumption and its prices, preparations are being made all over the world to expand the existing copper ore mines and to erect new ones.

3. According to Eng. and Mining Journal I, 1966, (pages 76-79), the production capacity of the mines being erected and newly opened in developed market economic countries and in developing countries amounted at the end of 1965 to more than 550,000 tons of copper in the ore. In centrally planned economy countries also new deposits have recently been discovered and new large copper ore mines are being opened.

4. It can be expected that in developing countries new copper-bearing deposits will be discovered and they will provide a raw material basis for the erection of new copper plants in these countries. Consequently, the preparatory action undertaken by the United Nations to set up the first meeting of copper experts who will discuss the most economic methods of the expansion of copper industry in developing countries, shall be considered as very justified and timely.

I QUANTITY AND QUALITY OF COPPER-BEARING RAW MATERIALS

5. The basic problem which should be fully solved before designing a new copper plant is the investigation of the resources of copper-bearing raw materials both as regards their quantity and quality. Usually, the erection and expansion of copper ore mines are gradual, their production capacity being increased year by year until the scheduled annual target output is reached. Some time after the underground construction of a copper ore mine has been started, the erection of an ore enrichment plant is begun. The time and quantity schedules for increasing the production of copper concentrates are the basic factors governing the correct design of copper plants.

6. Another factor is the thorough qualitative estimation of copper-bearing raw materials for the copper plant to be designed. There are many different raw materials for copper production; most frequently there are sulphide concentrates obtained by ore floatation enrichment. These concentrates are for the most part smelted by the conventional metallurgical methods. As raw materials can be used, rich sulphide ores containing more than 5 per cent of copper, which are then enriched or processed in blast furnaces, as well as oxidized ores are used and poor sulphide or mixed sulphide-oxide ores, which are processed by hydro-metallurgical methods.

7. Also, hard-to-enrich sulphide copper ores can be used as the raw materials which without being enriched are used as a direct raw material in copper plants, just as is the case in the Mannsfeld Combine, East Germany. Finally, a raw material for the bacteriological copper recovery is provided by poor sulphide or mixed sulphide-oxide ores or copper-bearing slag. In any case, even for the rough estimation of copper-bearing raw materials for every copper plant to be designed, it is necessary to carry out detailed chemical and minerological analyses of these raw materials for their content of non-ferrous metals, associated and rare metals for sulphur and slag-forming constituents, and to determine minerological compounds in which metals occur.

8. At present, due to the high price of copper, copper ores containing even less than 0.50 per cent of copper are exploited in strip mines, and sulphide ores down to 0.7 per cent copper content in underground mines.

II SELECTION OF THE MAIN PROCESS, THE COPPER MATTE SMELTING PROCESS

9. It is not yet possible to select for a copper plant to be designed the most suitable and economic processing method for raw materials whose chemical composition has already been determined. Two or three methods only can be selected, which should then be used in the investigation of the pilot processing of these raw materials.

10. The results obtained from the above pilot processing should be used in the comparative technical and economic analysis of these two or three methods. Of course, such an analysis requires the data on the possibility and cost of supplying this copper plant with electric power, various types of fuel, water, refractory materials, and the possibility and price of selling sulphuric acid from metallurgical works or, of supplying this acid to hydro-metallurgical works.

11. Below are given process directions which shall be followed in the selection of processing methods for copper-bearing raw materials to be employed in a copper plant to be designed.

Reverberatory furnace

12. The processing method most widely used all over the world for sulphide concentrates is their smelting in reverberatory furnaces to copper matte, which is then processed in converters to black copper. The concentrates processed by this method should not be high-melting and should contain at least as much sulphur as they contain copper. In addition, they should contain a sufficient amount of iron to combine with copper sulphides of copper concentrates and to give copper matte consisting of a complex mixture of copper and iron sulphides.

13. Since more than 80 per cent of primary copper is produced in the world by the application of reverberatory furnaces, it is necessary first of all to test and consider the possibility of melting the available concentrates in reverberatory furnaces. However, this method cannot be recommended for the production of less copper than 40,000 tons per year, since the modern, expensive reverberatory furnaces are constructed for an annual production of 40,000 tons of copper or more, being then fully economic in use.

Blast furnace

14. Blast furnaces for obtaining copper matte are relatively rarely used in the world. The largest amount of blast furnaces are operated in Japan. As the shortage of rich ores containing more than 5 per cent of copper steadily increases, the application of blast furnaces decreases. The smelting of copper concentrates in blast furnaces requires their briquetting or agglomerating, and these two processes are expensive. In Japan, a much cheaper method of lumping the concentrates has been introduced, involving their pelletization in disc granulators. A pelletized charge allows to obtain a smelting output of blast furnaces from 35 to 45 tons of charge per 1 square metre and 24 hours. In particular cases, sulphite copper ores and concentrates must be smelted in shaft furnaces, if the ores are difficult to enrich as in the Mannsfeld Combine, East Germany or the concentrates contain much bitumens and little sulphur in relation to copper as in Poland.

15. Rich oxidised, mixed or sulphide ores containing more than 5 per cent of copper can also be economically processed in modernised and intensified blast furnaces.

Electric resistance arc furnaces

Electric resistance arc furnaces are used for obtaining copper matte in eight countries of the world. Besides Bulgaria, no other country has recently built electric furnaces for this purpose. This method can be economically used on condition that cheap electric power can be obtained from water energy, natural gas or strip-mined brown coal. High-melting concentrates can successfully be smelted in electric furnaces which can be designed to produce copper matte at a rate corresponding to 25,000 to 50,000 tons of copper per year.

Flash smelting

16. Sulphur-rich concentrates can be smelted economically in autogenous flash smelting furnaces whose main advantages are that they operate without after-burning, and the gases obtained therefrom contain a high amount of sulphur dioxide and can be processed to sulphuric acid or liquid sulphur dioxide. The flash smelting method of smelting copper concentrates is used in five countries, including two firms of Japan. Flash smelting furnaces were built in Rumania and the Union of Soviet Socialist Republics in 1963 and the erection of such a furnace is contemplated in India.

The hydro-metallurgical method

17. A method widely used in the world for copper production is the hydro-metallurgical method which is however employed in some versions. Hydro-metallurgical methods can be employed for processing oxidized sulphide and poor mixed ores, ores which cannot be enriched for various reasons and, finally, copper ores containing considerable amounts of nickel and cobalt, which metals pass at low yields to concentrates during the floatation process. Depending on the nature of the deposit (acidic or basic), the following suitable versions of the hydro-metallurgical method are selected, (a) the leaching method by the application of sulphuric acid is used for raw materials containing silica deposit; (b) leaching method by the application of ammonia under pressure is used for raw materials containing alkaline deposits.

18. Acidic hydro-metallurgical methods can be employed in the plants producing from some thousands to some tens of thousands of tons of copper per year. On the other hand, the leaching methods employing ammonia under pressure are expensive and are recommended for plants producing more than 25,000 tons of copper per year, unless the powdered copper obtained is used in this same plant to produce expensive strips by sintering, just as is the case in the plant newly erected in Bagdad.

Bacteriological leaching

19. Supplementary to the above metallurgical methods is the method of bacteriological leaching of copper from slag employed in some plants. By these methods 119,250 tons of copper were recovered in the United States in 1962. The bacteriological method can also be used for the recovery of copper from sulphide or poor mixed copper ores.

Raw materials for this method must contain sulphur and iron which are processed by two species of the above mentioned bacteria.

III SIZE OF A COPPER PLANT AND PERSPECTIVES FOR ITS EXPANSION

20. The determination of the size of the copper plant to be designed depends first of all upon the size of the available deposits of copper-bearing raw materials. It is assumed that the available deposits should be sufficient for the exploitation and processing of copper ores within twenty five to thirty five years and the schedule of the increasing amount of the ores being exploited has much importance. However, there are no standard sizes of copper plants to be erected.

21. By selection of the chief technology of designed copper plants for an undeveloped country, it should also be taken into consideration the level of the technical culture in this country, as sometimes a modern but very complicated method can by its application in such a country bring more losses than profits, which could be expected from this method in comparison to the older but simpler method. The selection of the size of the individual stages in the erection of a copper plant depends not only on the availability of raw materials but also upon the nature and richness of copper ores or concentrates to be processed by this copper plant, that is, upon the method adopted for their processing in this copper plant.

22. High availability of raw materials for a copper plant, that is, a high exploitation capacity especially an underground copper ore mine, cannot be provided at once and consequently, a copper plant, particularly a smelter, must be erected usually in two or more stages. Since the time interval between the first and second stages of erection of a smelter must amount to a period of from five to ten years, it is necessary that even in the first stage such a plant should work economically.

23. The renumerability of a smelter depends to a large degree upon its yearly production, which in addition to the reasons appearing usually in such cases (cutting general works costs per 1 ton of product) is better because larger installations and furnaces can be employed in larger works. Larger furnaces have higher thermal efficiency due to lower heat losses and, in addition, larger works having larger installations and furnaces require less workers per each 1,000 tons of copper produced annually.

24. Directions will now be given regarding the size of new copper plants employing various processes, on the basis of the yearly production outputs of copper attained in copper plants depending upon the processes employed in these plants.

Yearly production per one reverberatory furnace

United States, Haydon	-	60,000 tons
Canada, El Passo	-	65,000 tons
United States, San Manuel	-	65,000 tons
Canada, Gaspe	-	40,000 tons
Yugoslavia, Bor	-	45,000 tons

25. Due to their expensive equipment, modern reverberatory furnaces have recently been built as large units only having a smelting capacity of 1,000 to 2,000 tons per 24 hours, which corresponds to a yearly production of copper of 40,000 to 80,000 tons. Consequently, the yearly production of a works having two reverberatory furnaces (first and second stages) can vary between 80,000 to 160,000 tons of copper.

Production capacity - blast furnaces

26. Production capacities of works having one blast furnace depend upon the richness of the charge; if blast furnaces operate on ore, the production of one blast furnace is too low to constitute the entire production of a smelter. More blast furnaces are then to be erected or this same works should have another installation employing a different process and determining the actual production level of the given works.

27. On the other hand, if one blast furnace operates on copper concentrate charges, the production of the works can amount to 40,000 tons of copper annually.

Table 1

Yearly production yields from one blast furnace in some smelters

Country	Works	Charge	Cross-sectional area of furnace (sq.m.)	Estimated production (in tons)
Belgium	Hoboken	Agglomerate of concentrates	7	35,000
Turkey	Ergani	"	6.7	35,000
East Germany	Liebknecht	Copper ore	18.34	5,000
Yugoslavia	Bor	Copper ore	7.1	5,000

28. By employing briquetted concentrate charges in a blast furnace having a cross-sectional area of 20 square metres, 50,000 tons of copper can be produced annually. It can thus be assumed that a copper works having one modernized blast furnace which operates on concentrate charges, will produce 50,000 tons per year. The amount of 30,000 tons of copper per year shall be adopted as the minimum payable production of a smelter having one shaft furnace, the maximum value being 50,000 tons of copper per year. Consequently, the entire works having two shaft furnaces (first and second stages) will produce between 50,000 and 100,000 tons of copper per year.

Of course, depending on the availability of raw materials, two such furnaces can be erected both in the first and second stages, and the total production of the works (first and second stages) will amount to 100,000 to 200,000 tons of copper per year.

Production capacity - arc furnaces

The yearly production capacities of four works having single arc furnaces are given in table 2 below.

Table 2

Yearly production capacity - single arc furnaces

Country	Works	Effective furnace power, kVA	Estimated yearly production per furnace (in tons)
Sweden	Rönnskar	10,000	35,000
Finland	Imatra	5,500	15,000
Bulgaria	Pirdop	16,500	45,000
Canada	Thompson	15,000	50,000

29. A minimum yearly production of 25,000 tons of copper and a maximum yearly production of 50,000 tons of copper shall be adopted for a works having one electric furnace. Consequently, the total production of the works (first and second stages) having two arc furnaces will amount to 50,000 to 100,000 tons of copper yearly.

Production capacity - flash smelting

Works with a single flash smelting furnace have an annual production capacity as indicated in table 3.

Table 3

Annual production capacity of works with single flash smelting

Country	Version of flash smelting method	Estimated yearly copper production (in tons)
Finland	Original Outokumpu method	50,000
Rumania	" " "	40,000
Japan	Japan-modified Outokumpu method	33,000
Canada	Inco flash smelting method	80,000

As can be seen from the above table, a works having one flash smelting furnace can be designed for a production of 30,000 to 80,000 tons of copper annually. Consequently the total production of such a works (first and second stages) having two flash smelting furnaces will amount to 60,000 to 160,000 tons of copper annually.

Production capacity - hydro-metallurgical works

30. For the most part, hydro-metallurgical works are designed for a production of 10,000 to 30,000 tons of copper annually except for two works of this type, the

Chuquicamata Works in Chile and the Kolvezi Works in Africa, therefore a production of 20,000 to 30,000 tons annually can be assumed as economically large for a hydro-metallurgical works.

31. By assuming the production capacity of the second expansion stage of a hydro-metallurgical works to be equal to that of the first expansion stage, the total production of the works (first and second stages) will be from 40,000 to 60,000 tons of copper annually.

Production capacity - bacteriological methods

32. Copper plants employing bacteriological methods are in the development stage only and are not separate plants but for the most part are expanded in conjunction with copper works, consequently no conclusion as to their size can be drawn as yet.

IV. SELECTION OF BUILDING SITE AND PERSPECTIVES OF EXPANSION

33. The correct selection of a building site for a copper plant has a great effect on the correct operation of the plant, and to a large degree contributes to its renumerability.

Direct production

34. If a copper plant is to process directly ores without their enrichment, it must be located close to a copper mine. Thus, hydro-metallurgical plants, plants employing bacteriological recovery of copper from ores, and copper works having blast furnaces for smelting rich ores must be located in the neighbourhood or very close to copper mines, but in the latter case it is necessary to provide a barrier pillar below plants or works, which makes it more difficult to extract later ore from below it.

Copper production from concentrates

35. If the copper-bearing raw materials for a copper works are to be provided by copper concentrates, the selection of the building site of such a works is less limited. In selecting the location of a copper works account should be taken of the convenient and cheap transport of concentrates from an enrichment plant to the copper works. The cheapest among transportation methods is by water, this being possible when the enrichment plant is close to a river or sea which, however, is of rare occurrence. If there is a railway close to an enrichment plant, a copper works should be located close to this railway if not hindered by other considerations. In some cases, copper concentrates in the form of a pulp are transported from an enrichment plant to copper works over some distance. The settling tanks and filters for separating water from the concentrates are then erected close to those copper works.

36. Developing countries are for the most part in zones free from frost, and such a transport would not be troublesome or expensive. For some location alternatives selected, it is next necessary to consider the best and cheapest supply of fluxes, electric power, coal, oil, gas, coke and water, taking into account two or three alternative processing methods initially selected for a works.

Building site

37. It is not recommended to select the building site of a copper works in fertile or wooded areas since, at a later stage, it has a detrimental effect on trees and crops and also can force a copper works to pay high indemnities for the losses incurred.

Dispatch of sulphuric

38. Essentially, a copper works shall be able to sell its sulphuric close by so that the value of dispatch should not exceed that of the sulphuric acid being sold. Should it be impossible, a high chimney should be designed that all the gases containing sulphur dioxide may be removed from a copper works.

Available fluxes

39. It is desirable to find close to the selected location of a copper works the deposits of gold-bearing sand to be used as a flux and an additive for convertors. Should such a sand be not available, quartz and limestone should be available from a short distance for use as fluxes.

Erection of plant

40. The building site for a copper works should be relatively flat, but it is desirable that a hill should be available on the site or close by to erect a chimney and thus to save on height. The soil on the site shall be relatively strong so that the erection of deep foundations could be avoided.

Dispatch of copper and copper products

41. It is necessary to examine the expected directions of dispatch of copper or, possibly, its semi-products and by-products, so that transport should be convenient and cheap.

Staff for plant

42. For ensuring a better acquisition of good specialists for a copper works and preventing fluctuations of the crew, it is recommended to locate a copper works close to a town where the workers and their families could find recreation, shops and schools for their children. Of course in such a case a copper works should be located relative to the town with wind rose and sanitary zone taken into account.

Workers settlement

43. The location of a copper works close to a town permits a saving of outlay for erection of workers' settlement.

V. REVIEW OF PROCESSING METHODS AND EQUIPMENT

Treatment of copper concentrates

44. For the most processes employed for obtaining copper matte from copper concentrates the latter must be dried to a moisture content of 8, 6 or 4 per cent, and for flash smelting furnaces to 0.5 per cent. Most widely used are rotary driers and recently, vertical tube blast driers have been inducted. Below are given some of the outputs attainable with the use of rotary driers for drying copper concentrates.

Table 4

Attainable outputs with use of rotary driers

Country	Works	Initial moisture in %	Final moisture in %	Drier dimensions in metres	Charge output tons/hour	Water evaporation intensity kg/m³/hour
Finland	Hariavalta	7 - 8	0.5	D=2,2 L=24	25	30
Canada	Fin Flon	18 -19	9- 10	D=2,7 L=24	70	56
Finland	Kieriotta	10 -11	6	D=1,7 L=10	20	45

Furnaces for pre-roasting

45. In many copper works use is made for concentrate roasting of Wedge and Hereshof furnaces. In centrally planned economy countries, fluosolid furnaces for concentrate roasting have been gaining in popularity for ten years, and they have fully replaced the Wedge and Hereshof roasters. The former are cheaper than the latter both as regards cost of erection and operation. A fluosolid roaster is used in the Tennessee Works, United States, for roasting copper concentrates which are charged into the furnace in the form of a pulp mixed with sand at a ratio of six parts of the concentrate to one part of sand. The latter is used to form and maintain in the roaster a permanent fluidized bed. A roaster of an area of 10.5 square metres precalcinates 250 tons of copper concentrate per twenty-four hours. An output of 250 tons per twenty-four hours can be attained in a Wedge and Hereshof roaster of 33 square metres and having ten hearths. A considerably higher output can be attained in a fluosolid furnace by roasting granulated concentrates, amounting to 50 tons of charge per 1 square metre area of hearth per one hour.

<u>Reverberatory furnaces for obtaining copper matte</u>

46. In recent years many improvements were introduced in the construction of reverberatory furnaces such as, replacement of dinas lining by magnesite and chrome-magnesite linings; suspended furnace roofs; considerably greater furnace widths and lengths; caissoning the hottest parts of furnace walls; introduction of air pre-heating and application of cheap natural gas or fuel oil instead of coal dust for furnace firing. The introduction of the above mentioned improvements made it possible to increase considerably the daily throughput of reverberatory furnaces up to 1,500 tons of charge and even up to 2,000 tons. Table 5 presents the data for some reverberatory furnaces.

Table 5

Reverberatory furnaces

Country/Works	Internal furnace dimensions metres	Roasted or raw charge	Charge of smelting tons per 1 sq.m. per 24 h.	Consumption of conventional fuel in per cent of charge	Type of fuel	Copper matte per cent of copper	Waste slag, per cent of copper	Year of construction	Annual copper production per furnace (in tons)
United States, Haydon	34,8x9,3	raw	2.9	-	gas	27.2	0.34	reconstr. 1959	60,000
Canada, El Passo	34.2x6.56	roasted	5.4	12.0	gas	35.0	0.45	1956	65,000
United States, San Manuel	31.1x9.76	raw	2.4	18.3	gas	32.0	0.40	1956	65,000
Canada, Gaspe	30.2x7.8	raw	2.6		oil	29.0	0.27	1955	40,000
Canada, Noranda	31.2x10	roasted	4.45	10.65	coal dust	24.4	0.37	-	-
Yugoslavia, Bor	27.4x7.3	roasted	5.2		coal dust	35.0	0.40	1961	45,000
Union of Soviet Socialist Republics	32.0x8.0	raw	3.5	20.0	gas	24.0	0.45	1963	-

47. The use of roasted concentrates for smelting allows a higher smelting output per 1 square metre of furnace hearth and a lower fuel consumption. On the other hand, the use of raw charge obviates the roasting operation which causes a loss of copper due to dusting and permits the use of fewer fluxes thus decreasing the amount of slag which contains less copper and, as a result, the copper yield to the copper matte when smelting raw concentrates is higher by about 3 per cent. Consequently, the smelters disposing of a cheap fuel, such as natural gas, switch over to raw charge, just as the Garfield smelter, United States, has already done. The Hayden smelter, United States, employed roasted charge before reconstruction in 1959 and received slag containing 0.45 per cent of copper; after the reconstruction and the application of raw charges, it produces slag containing 0.34 per cent of copper.

Blast furnaces

48. Newer blast furnaces have squares in cross-section which amounts to 20 square metres. In order to intensify their operation, blast air is pre-heated and the briquetting process is improved by substituting stamp briquetting machines by high-pressure roll briquetting machines. Particularly high charge smelting output per 1 square metre of blast furnace cross section is obtained by employing for smelting in these furnaces the sintered charge, that is, the agglomerate. However, concentrate sintering is expensive and can be used for sulphur-rich concentrates only.

Table 6

Technical indices for some blast furnaces

Country Smelter	Charge Type	Cross-sectional area of furnace	Coke consumption, kg per ton of charge	Smelting output, t/m^2 per 24 hours	Copper content of matte %	Copper content of slag, %
Belgium, Hoboken	Agglomerate	7	125	85	41	0.41
Turkey, Ergani	"	6.7	90	90	35	0.5
Germany (Fed. Rep.) Liebknecht	Ore	18.34	185	44	42.8	0.18
Yugoslavia, Bor	1/3 agglomerate and 2/3 ore	7.1	180	54	43.3	0.31

49. Oxygen-enriched air has been used experimentally as the blast air in one of the Union of Soviet Socialist Republic's smelters; as a result, the smelting output was increased by 15 per cent and the coke consumption was lowered by 20 to 25 per cent. The blast-furnace top gas containing more than 16 per cent of carbon monoxide is used in some smelters for firing boilers after having been mixed with usual fuel; in such a case the utilization factor for the heat obtained from the coke used in blast furnaces is about 70 per cent and this without the application of expensive waste-heat boilers, as is the case with reverberatory furnaces.

50. The size of a blast furnace can be adapted to the amount of the raw materials available without lowering the technical indices obtained with it. Depending on the magnitude of the cross-sectional area at the tuyere level and the percentage copper content of the charge used, one single blast furnace can yield an amount of copper matte corresponding to a production output of metallic copper amounting to 15,000 to 50,000 tons per year.

Electric resistance arc furnaces

51. Electric resistance arc furnaces for obtaining copper matte are used in only a few countries but, nevertheless they have some important advantages:

(a) with cheap electric power generated by water force, natural gas or brown coal, they can be more economical than other furnaces;

(b) they are particularly suitable for smelting highly fusible copper concentrates;

(c) the amount of gas developed in electric furnaces is smaller than in other furnaces and dust exhaust equipment can thus be smaller;

(d) the concentrate charge is only dried, granulated or pre-roasted when the sulphur content is high, but in this case, when hot charge is used for electric furnaces the smelting output per 1 square metre of furnace area increases and the consumption of electric power for smelting decreases.

Table 7

Technical and economic indices of electric furnaces

Country, Smelter	Active power of furnace kVA	Furnace area m^2	Furnace load kVA per $1 m^2$ of furnace area	Charge type	Smelting output, tons per $1 m^2$ of furnace area	Consumption of electric power, kWh per 1 ton of charge	Annual copper production per 1 furnace (in tons)
Sweden, Rönnskär	9,000	111	70	roasted	5.0	390	about 35,000
Finland, Imatra	5,500	55	106	40% roasted	4.7	509	about 15,000
Bulgaria, Pirdop	16,500	118.6	140	roasted	7.0	420	about 45,000
Canada, Thompson	15,000	184	80	roasted	4.5	375	about 50,000

Just as blast furnaces, electric furnaces can be adapted to smaller amounts of raw materials available for a copper production of a smelter having one electric furnace, amounting to 15,000 to 50,000 tons annually.

Flash smelting concentrates in furnaces

52. The method of flash smelting concentrates in furnaces has been slowly gaining popularity in recent years. This method can be used for smelting sulphur-rich conc trates. In contrast to other metallurgical methods, its important advantages are as follows, autogenous concentrate smelting, i.e. requiring no additional fuel; and possibility of using sulphur dioxide obtained in the gas generated in flash smeltin furnaces for the manufacture of sulphuric acid or liquid sulphur dioxide.

53. The disadvantages of the method are the necessity of drying concentrates down to a moisture content of 0.5 per cent and the high copper content of primary slag and necessity of lowering this content. The method of concentrate smelting ha been developed and used in Finland for many years. Concentrates dried down to a water content of 0.5 per cent are blown with air heated to 550°C into the furnace shaft in the Hariavalta Smelter of the Outokumpu Company. The products of reaction fall down into the furnace tank, where the reaction of copper matte production is completed, slag is produced and these two products are separated into layers by mak use of their different specific gravities. The gas escaping from the furnace conta 17 per cent of sulphur dioxide and, after dust has been removed, it is processed in sulphuric acid.

54. The slag removed from the flash smelting furnace of the Hariavetta Smelter contains 1.4 to 1.5 per cent of copper and, together with converter slag it is processed upon size reduction and grinding by floatation, thanks to which the copper content of slag drops down to 0.3 per cent and a concentrate containing 20 per cent of copper is obtained. In the Copper Cliff Smelter of Canada use has been made for smelting copper concentrates in a flash smelting furnace of technical oxygen contai 95 per cent of oxygen instead of preheated air. The gas obtained from the furnace contains about 80 per cent sulphur dioxide and is processed to liquid sulphur dioxi

55. The slag obtained from the flash smelting furnace of the Copper Cliff Smelter is processed additionally in a reverberatory furnace of the nickel department of th smelter by adding pyrite to decrease the copper content down to 0.57 per cent. The oxygen consumption by the flash smelting furnace of the Copper Cliff Smelter amount to 240 kg per 1 ton of charge. As a result of the improvements introduced into the furnace design and process, the daily furnace charge has recently been increased up to 1,500 tons, which corresponds to a yearly copper production of about 80,000 tons

56. One flash smelting furnace has been erected in each of two smelters in Japan for concentrate smelting to copper matte according to the Japan-improved Outokumpu

method. These are the Ashio Copper Smelter and the Turahawa Smelter. In the latter smelter, the yearly copper production amounts to 33,000 tons.

Copper matte converting

57. All the above-mentioned metallurgical methods of copper concentrate smelting give copper matte consisting of a mixture of copper and iron sulphides. The converting process takes place in oxidising atmosphere and its purpose is to convert iron to slag in the form of iron silicate, sulphur to gas in the form of sulphur dioxide, and copper to raw metallic copper. The present operation in converters is periodic, the cycle of large converters amounting to twelve to fifteen hours.

58. In the majority of the world's smelters, the converter gas containing 4 to 6 per cent of sulphur dioxide is used in the manufacture of sulphuric acid. The value of sulphuric acid produced in copper smelters at a price of $US29 per ton and the price of copper amounting to $US1,100 per ton, is about 5 per cent of the value of the copper produced. The processing of converter gas to sulphuric acid also decreases damages to the trees etc., surrounding a smelter and also the penalties a smelter would be obliged to pay for releasing such a large amount of sulphur dioxide into the atmosphere.

59. In order to ensure a possibly uniform amount of gas and a sufficient sulphur dioxide content of the gas for a sulphuric acid factory, usually three to five converters are erected whose working cycle is suitably shifted so that two of them are always in blast.

60. The converters designed in the Hoboken Company of Belgium have axial gas discharge and fully catch all the gas and attain its sulphur dioxide content equal to about 8 per cent; however, to ensure a constant amount of gas, two types of Hoboken converters at least should always be kept in blast. The converters of this type are gaining increased popularity the world over. At present, however, type Pierce Smith converters, 4 m in diameter and 9.15 m in length are used in the majority of smelters as standard units. Below are given the characteristics and outputs of such converters installed in some smelters.

Table 8

Pierce Smith converters used in some smelters

Country Smelter	Number of converters	Number and diameter of tuyeres, mm	Minute air supply to converter, normal m^3	Converter output: Tons of copper per 24 h.	Converter output: Tons of copper per overhaul life of lining
Chile, Braden Copper	4	41x38	320-354	160	18,000
Chile, Exploration	4	20x50		150	17,5000
North Rodesia, Rokana	5	45x51	285-570	167	9,140
United States, Chino	3	48x38	594	121	20,118
United States, Magma	3	42x38	515-630	110	15,000
Canada, Gaspe	2	48x47	520-660	140	9,000

61. Since the oxidation process of impurities of raw copper and their removal to slag takes place in converters much more rapidly than in anode furnaces, the converter process is now being run a little longer for overoxidation of copper to an oxygen content of copper amounting to 0.6 per cent.

Smelting of pelletized concentrates

The smelting method of pelletized copper concentrates together with copper matte in converters with the application of oxygen-enriched blast has been developed and used in the Hitachi Smelter, Japan. The oxygen consumption is 225 normal m^3 per 1 ton of concentrate. Thus, a large portion of the concentrate by-passes one expensive operation, the manufacture of copper matte; however, this requires the use of oxygen. This is a question of economy for every country whether such an amount of oxygen is cheaper or the cost of concentrate melting to copper matte is lower.

Refining anode furnaces

62. Recently, there are two refining methods employing refining furnaces; one, wherein stationary furnaces are used, and the other employing tilting cylindrical furnaces. Already 25 tilting furnaces are used in 14 smelters. The advantages of these furnaces are as follows -they can be installed at right angles to each other and at a tangent to one circular casting machine, thus swing one circular casting

machine; easy control of tapping rate by gradual furnace tilting; easy lining with wedge-type blocks and considerably shorter refining cycles as compared with those of stationary furnaces. Cylindrical tilting furnaces are usually constructed for copper capacities of 160 to 250 tons. The refining cycle in these furnaces, including tapping operation, does not exceed eighteen hours if molten copper charge is used.

63. Stationary furnaces are currently being built in large copper smelters for copper capacities of 300 to 500 tons. In order to shorten the copper tapping time, two circular casting machines are intended for each furnace, and each of them has a copper capacity of 40 tons per hour. A full refining cycle takes about twenty four hours. In large stationary furnaces roofs are made of basic suspended blocks, just as in reverberatory furnaces. Recently, converted natural gas or sulphur-free fuel oil is used instead of wood for copper reduction in anode furnaces, the above mentioned raw materials being three times cheaper than the wood.

Copper electrorefining

64. The majority of electrorefining plants employ electrolysers each having a total active cathode area of 50 to 60 square metres and operated at about 12,000 A. Few plants (Garfield and Montreal) employ current of 15,000 and 18,000 A and a correspondingly large cathode area per one electrolyser. The general tendency is to increase current density from below 200 A/m^2 to 220 A/m^2 and even 258 A/m^2 of cathode area. Below are tabulated the plants wherein current densities in excess of 200 A/m^2 are employed.

Garfield	204	El Pasco	220
Barber	208	Laurell Hill	225
Cerro de Pasco	212	Nkana	235
Baltimore	220	Great Falls	250
Inspiration	220	Montreal	258

65. Refining plants having anode copper with a high silver content in the order of 4,000 to 7,000 grammes per ton must employ a lower current density (about 170 to 180 A/m^2) in order to decrease the loss of silver to cathode copper and to prevent partial anode passivation. These are the following plants: Oroya in Peru and the Mannsfeld Combine in East Germany. The consumption of electric dc power in copper electrorefineries having anodes with a low silver content amounts to 200 to 300 kWh per 1 ton of cathode copper.

Cathode copper melting and tapping of copper for wire-bars

66. In many copper smelters cathode copper is still melted in stationary furnaces and is then poured into ingot moulds arranged horizontally on the circular casting

machine. Stationary cathode copper melting furnaces are fired with gas or oil and their size depends on the size of the smelter. They are constructed for copper capacities of 200 and 300 tons. Their working cycle takes about 24 hours. For more than a dozen years, continuous vertical casting of wirebars has been introduced, which required a suitable adaptation of melting and foundry furnaces, since these functions have been distributed between two separate furnaces.

67. Due to the height required for vertical casting, these furnaces should be located high. There are not flame-heated furnaces still, but electric furnaces of small capacity but high output. The first, melting furnace, is constructed as an arc or induction furnace with a copper capacity of 25 to 50 tons. The second, foundry furnace, is of the induction type, has a capacity of fifteen tons and is used only to attain and maintain temperature characteristics of copper casting. A set of such furnaces comprising a unit for the continuous casting of wirebars has an output of 25,000 to 30,000 tons of copper annually.

Dedusting of gases from metallurgical processes

68. The equipment mentioned below is commonly used for dedusting the gases emerging from the units for smelting concentrates to copper matte - waste-heat boilers wherein the coarsest dust particles are separated; a channel with hoppers for dust release; cyclones and batteries of multi-cyclones and dry electro-filters. The dust content of the gases emerging from dry electrofilters is about 0.2 grammes per normal cubic metre. The equipment commonly used for removal of dust from converter gas is as follows - a long balloon channel with hoppers for dust release; cyclones; batteries of multi-cyclones and dry electrofilters. The condition for the efficient operation of electrofilters is that gases should be preliminarily dedusted down to about 2 grammes per 1 normal cubic metre.

VI MECHANIZATION AND AUTOMATIZATION

69. Although the main purpose of this article is to provide directions for designing copper plants in developing countries wherein manpower is freely available, it is the considered opinion of the author that in these countries new plants to be erected should be automatized for the following reasons:-

(a) automatic control of processes ensures their proper course since the human mind is not capable of being fully concentrated over the entire period of his daily work;

(b) some changes of process parameters take place so rapidly that men cannot react to them quickly enough and to oppose undesirable changes of process parameters;

(c) great deviations of established process parameters may not be allowed, since this lowers the technical and economic indices of processes; it is only automatic instruments that are capable of satisfactorily coping with this problem;

(d) automatic process control also ensures a higher and more uniform product quality.

70. A full automatization of a smelter costs at present 6 to 8 per cent of the total cost of machinery and equipment but it still pays, were the technical and economic indices of an automatized and a non-automatized smelter compared over a sufficiently long period of time. For example, excessive temperature rises in a reverberatory furnace fired without automatic control, causes damage to the furnace roof, thus leading to its shut-down for several days for performing an overhaul. Now, several items of a modern smelter will be discussed with the view to mechanization and automatization.

Stores

71. Mechanize the operations of unloading all raw materials, fluxes, fuel and auxiliary materials. Mechanize and eventually automatize the operations of handling raw materials and fluxes from stores by their automatic feeding from silos.

Concentrate roasting

72. Automatize the roasting process by automatically feeding the charge and the amount of air supplied to the furnace depending upon the temperature in a fluo-solids furnace or upon the temperature of the Wedge roaster hearths. Additionally, the supply of air for cooling the rabble arms of Wedge roasters depending upon the temperature of escaping air from arms, shall be automatized.

Reverberatory furnaces

73. Automatize the adjustment of furnace firing and the supply of charges to a furnace depending upon the furnace temperature measured by means of a radiation pyrometer. Provide water supply to caissons depending upon the temperature of outlet water. Automatize the adjustment of the ratio between air and gas supplied to the furnace burners. Automatize the adjustment of the operation of the heat exchanger placed behind the waste-heat boiler in order to maintain constant temperature of the air supplied to the furnace. Automatize the operation of filling the charge tanks by isotopic methods. Mechanise and automatize the transport from tanks and the operation of loading the charges into the furnace. Automatize the regulation of the exhaust of gases from furnaces to maintain a small constant underpressure in these furnaces. Automatize the operation of cleaning the waste-heat

boiler tubes of the dust settled therein, and of removing and transporting this dust. Employ pneumatic or vacuum transport for handling dust from the above as well as from any other gas dedusting units over long distances, and closed vibratory tubular conductors or rotary tubular conveyors with spirals inside the tubes, over shorter distances.

Blast furnaces

74. Mechanize and automatize the feed of copper-bearing charge, fluxes and coke depending upon the data of the isotopic charge-level indicator. Automatize the adjustment of the pressure and amount of the blast supplied to furnaces. Automatize the adjustment of the operation of the preheater of the air supplied to furnaces to maintain constant blast temperature. Automatize the adjustment of the temperature of the water flowing out of caissons.

Resistance arc furnaces for the production of copper matte

75. Automatize the feed of charges to furnaces depending upon the furnace temperature measured with a radiation pyrometer. Automatize the adjustment of the operation of lowering the electrodes as they become consumed. Automatize the adjustment of the current load of furnaces depending upon the feed rate of charges and the furnace temperature. Automatize the adjustment of the exhaust of gas from furnaces in order to maintain a small constant underpressure in these furnaces.

Flash smelting furnaces

76. Automatize the adjustment of the air preheater for furnace firing in order to maintain the constant air temperature. Automatize the feed of charges and air to maintain constant temperature in the furnace measured with a radiation pyrometer. Automatize the adjustment of the exhaust of gas from furnaces in order to maintain a small constant underpressure in these furnaces. Automatize the adjustment of the quantitative ratio of the air supplied to furnaces to the amount of the charge blown in order to maintain a constant sulphur dioxide content of gas.

Converters

77. Employ mechanical units for tuyere cleaning as those constructed in the Mac Hill Smelter, United States and already used in some other smelters. Automatise the adjustment of the amount and pressure of the air supplied to tuyeres depending on the temperature in the converter, or upon the temperature of the gas escaping from the converter. Mechanize the operation of adding silica to converters in order to ensure its uniform feed to converters during their first stage of operation. Automatise the

operation of reverse tilting of converters in case of an interruption in the power supply to the blower driving motors. Mechanize the operation of tapping converter slag.

Refining furnaces

78. Automatize the adjustment of furnace firing depending upon the final furnace temperature, that is, before copper tapping in order to establish and maintain the correct temperature of copper. Mechanize the operation of removing anodes from ingot moulds on the circular casting machine and of placing them into a basin containing water. Automatize, just as in the Hariavalta Smelter, Finland, the operation of casting anodes into ingot moulds on circular casting machine by the automatic (suitably shifted in time) coupling of the operations by tipping and elevating the pouring cradle to the operation of indexing the circular casting machine with ingot moulds in order to obtain anodes to the least weight difference.

Copper electrorefining

79. Automatize the supply of colloids to electrolytes. Automatise the adjustment of the temperature of the electrolyte circulated. Mechanize the preparation of cathodes from copper starting sheets obtained in separate electrolysers. Automatize the adjustment of the amount of the electrolyte supplied to the individual groups of electrolysers. Mechanize the operation of washing cathode copper. Employ the vacuum evacuation of electrolysers of anode sludge and its transport to sludge processing department.

Cathode copper melting furnaces

80. Automatize the adjustment of firing stationary furnaces in order to maintain the correct furnace temperature at various stages of furnace operation, and the correct temperature of copper during its tapping. Automatize the operation of casting wirebars into ingot moulds on circular casting machine in order to obtain wirebars with small weight differences. Automatize the removal and transport of wirebars from circular casting machine to transport cars or continuous transport direct to stores. Automatise the operation of induction foundry furnaces in order to maintain a correct constant temperature of the copper being cast. Automatize fully the operation of the vertical continuous wirebar casting unit.

Dedusting of metallurgical gas

81. Automatize the adjustment of the temperature in front of dust removal units. Automatise the adjustment of the voltage of electrofilters. Mechanise and automatise the operation of bad dedusting in bad dedusting units. Mechanise and automatise the

removal and transport of dust from dedusting units. Automatize the adjustment of the pressure in dedusting units.

Sulphuric acid plant employing the contact method

82. Automatize the adjustment of the temperature and concentration of sulphuric acid for gas drying towers. Automatize the adjustment of the temperature of gas in front and behind the contact reactor. Automatize the adjustment of the temperature and concentration of sulphuric acid supplied for absorption. Automatize the adjustment of the concentration of the acid flowing out of the absorber, i.e. of the finished product. Automatize the operation of filling the acid tanks supplying the drying and absorption towers. Automatize the operation of checking the acidulation of water for cooling the acid in drip coolers in order to quickly detect leakage therefrom.

Concentrate dryer

83. Automatize the operation of feeding concentrates to the dryer, and the adjustment of the operation of firing the driers in order to maintain a constant temperature in the dryer. Automatic interlock of the operation of the units transporting and feeding charges to furnaces is necessary in the case of the failure of a given furnace to prevent additional damages and troubles.

Central control room

84. It is recommended to install in large smelters a computer for recording the data automatically transmitted from departmental control rooms or direct from control apparatus. A computer will process the data obtained and compute metal yield, production, general and unit consumption of raw materials, fluxes, electric power, fuel, water, steam and other quantities required by the smelter management.

VII PROCESS CONTROL

85. In order to ensure proper process control it is necessary, in addition to the automatic instruments mentioned to install many other instruments for the determination and record of process parameters. The majority of these data can and should be transmitted additionally to departmental control rooms or to the central control room. Important for the accurate preparation of metal balances is the installation of automatic recording scales on the conveyors handling raw materials, semi-products and waste. At the same places, automatic samplers and sample grinding, homogenising and decreasing equipment should be installed. The overhead travelling cranes (in

stores) mounting the scales shall also have tele devices for transmitting the data on the consumption of raw materials or fluxes to a proper control room. It is very important to set up a proper service in sections and departments to control the quality of semi-products handled among them. Improper control and handling of semi-products of low quality will result in impairing frequently the quality of the end product, copper, in addition to lower metal yields and increased consumption of power or materials.

86. If, for example, inspectors will release poorly refined or cast anodes, the consumption of electric power for electrorefining will increase and cathode copper will be of inferior quality. Large smelters comprise usually small department laboratories and a central works laboratory. In order to prevent doubling the apparatus which fairly frequently is expensive it is recommended to provide work to department laboratories in such a way that all frequently repeated current analyses should be carried out in them, all other analyses being carried out in the central laboratory.

VIII QUALITY OF PRIMARY AND SECONDARY PRODUCTS

87. The main products of a copper smelter are usually: converter copper if a smelter does not comprise an electrorefining unit; cathode copper sold partially in such a condition; electrolytic copper remelted into wirebars, blocks, blooms, ingots and billets; sulphuric acid; refined silver; refined gold; nickel; selenium and tellurium; pavement setts (the Mannsfeld Combine, East Germany) or pavement setts and back-filling pipe inserts (the Legnica Copper Smelter, Poland) obtained from waste slag of blast furnaces.

88. As regards quality, only extracts from British Standards and from those provided by the Council of Mutual Economic Assistance of Socialist Countries will be presented below.

Extracts from British Standards for Copper

B.S. 1035 : 1964. Cathode Copper

Chemical Composition

Copper (silver being counted as copper) - not less than 99.90 per cent.

Impurities

Bismuth	not more than	0.0010 per cent
Lead	not more than	0.005 per cent

Total (excluding oxygen and silver) - not more than 0.03 per cent

Cathodes shall be tough, dense and free from loose or brittle lumps, nodules and other excrescenses. The surface shall be free from slime and from copper sulphate.

BS 1036:1964 Electrolytic tough pitch high conductivity copper

<u>Chemical composition</u>

Copper (silver being counted as copper) - not less than - 99.90 per cent

<u>Impurities</u>

Bismuth	not more than	0.0010 per cent
Lead	not more than	0.005 per cent

Total (excluding oxygen and silver) - not more than 0.03 per cent

The material shall normally be supplied as wire bars, cakes, or billets, ingots or ingot bars.

The material shall have been passed through an electrolytic refining process before being remelted and cast into the required shapes.

Wire bars, cakes, slabs and billets shall be free from harmful physical defects such as shrink holes, cracks, cold sets, pits, raised edges and other defects in set or casting.

<u>Electrical resistivity</u>

The electrical resistivity of the material, measured in accordance with Clause 6 of Section One shall not exceed the following values :

<u>Table 9</u>

<u>Electrical resistivity</u>

Form	Resistivity at 20°C max. ohm.g./m²
Wire bars	0.15328
Cakes, slabs and billets (when specified for electrical purposes)	0.15328
Cakes, slabs and billets (per other purposes)	0.15694
Ingots and ingot bars	0.15694

<u>The electrical resistivity test</u>

The resistivity shall be determined on material in the form of drawn wire approximately 0.080 inch (2.03 mm) diameter, which has been annealed at a temperature of 500°C to 550°C for not less than 30 minutes.

B.S. 1433:1964 Copper for electrical purposes.

Electrical resistivity

O-soft	-	0.01737 ohm mm^2/m
1/2 H-half hard	-	0.01777 ohm mm^2/m
H-hard	-	0.01777 ohm mm^2/m

Both sorts of copper : 1/2 H and H when annealed have the electrical resistivity - 0.01737 ohm mm^2/m. The chemical composition of this copper should be as copper defined in British Standards :

BS 1035:1964 and BS 1036:1964.

The Standards for Copper in United States are very similar to the British Standards.

The socialist countries belonging to the Council of Mutual Economic Assistance EMPC established a standard for various copper grades, designated PC 75-64; two copper grades considered in it being presented below :

cathode copper	99.95 % copper
melted cathode copper	99.90 % copper

Table 10

Extract from a RKPG standard for two copper grades

Designation of copper marks	Copper grades	Chemical composition													Application
		Copper, min	Impurities, not more than												
			Bi	Sb	As	Fe	Ni	Pb	Sn	S	O	Zn	Ag	P	
Cu 99.95 K	Cathode copper	99.95	0.001	0.002	0.002	0.005	0.002	0.005	0.002	0.005	-	0.005	0.003	-	Semi-products for electrical purposes and high quality alloys
Cu 99.90	Melted cathode copper	99.90	0.001	0.002	0.002	0.005	0.002	0.005	0.002	0.005	x/	0.005	0.003		

x/ Oxygen content

The electrical resistivity of soft wire, made of mark Cu 99.90 copper for electrical purposes and having a chemical composition as shown in Table should not be more than 0.01724 ohm mm^2/m.

IX MAIN PROBLEMS IN ERECTION OF METALLURGICAL WORKS

89. In order to facilitate and speed up the decision of the extension of a works, it is necessary to undertake geological prospecting sufficiently early to determine the possibility of increasing the amount of the raw materials available. A building site shall be selected to permit the future extension of a works to double or treble its production capacity provided for in the first stage. Additional outlays for the second stage during the erection of the first stage of a works can be used in order to cheapen the erection of the whole works to a larger or smaller degree depending on the time interval after which the second stage will be erected. The reason is that it can be economic to freeze additional outlays for the second stage during a short period of time, if it will decrease the total outlays for the erection of the two stages of the works. This will, however, be uneconomical if the time interval between the two stages is too long.

90. After the above economic aspects have been taken into account, the following preceding outlays for the second stage can be considered in the erection of the first stage :-

(a) to install during the first stage the gas and water pipelines and electric conductors having a throughput sufficient for the two stages of a works; or

(b) to install in the first stage the channels to accommodate cables, gas and water pipelines, etc., of a greater cross-sectional area capable of accommodating additional cables and pipelines to be laid down in the second stage; and

(c) to construct foundations for large converters required for the two stages, and to install on them smaller converters in the first stage.

91. It is not recommended to erect during the first stage the administration, workshop, storage and other auxiliary buildings of a size required for the two stages, but to design them so that they can be extended during the second stage without high costs and trouble. The preceding geological prospecting will provide the data on whether the copper-bearing raw materials for the second stage will be similar to those of the first stage. This will make it easier to evolve a general plan of the whole works. Should the raw materials and the respective processes be different for the second stage, the latter shall provide for a separate works located close to the part erected during the first stage. This will of course increase the cost of erecting the second stage.

92. Underdeveloped countries are usually in the regions of hot or warm climates and, consequently many units can be installed outdoors or under an open shed,

which will also facilitate future extension of the works. The present trend in building industrial works consisting in connecting small buildings into larger buildings which accommodate several production departments lowers the cost of erecting the first stage, but can present great difficulties and require additional costs for designing and erecting the second stage.

93. If the two stages are to provide a uniform works of a productiveness higher than that during the first stage, the individual items of equipment of every production department for the two stages should be installed close to one another. Consequently, in evolving the general plan of the whole works the above problem should be considered in detail with the provision of suitable means of transport between the individual production shops for the second stage being taken into account. A single reverberatory furnace should have two waste-heat boilers since these units require frequent repairs and a modern reverberatory furnace can be operated without major repairs for many years.

94. During the first stage, both the reverberatory furnace and the waste-heat boilers should be installed so that during the second stage one waste-heat boiler only can be erected for the second reverberatory furnace, and the stand-by boiler of the first stage can use alternately the gas from either of the reverberatory furnaces. Stationary anode furnaces should be designed so that during the second stage they can be extended to increase their capacity by 100 per cent instead of erecting new furnaces at a much higher cost. The same recommendation applies to cathode copper melting furnaces.

95. After the second stage of a metallurgical works has been completed the immediate surroundings of a works become much dusted and gassed. If a smelter is located in an agricultural or woody region, the release of additional gas containing dust and sulphur compounds will exceed the content provided for by sanitary regulations. Consequently, it is recommended to erect a chimney of sufficient throughput and height during the first stage (if the second stage is not much distant in time) so that harmful gas can be released from the whole works at a sufficient height to distribute and dilute it in the upper atmospheric layer. This problem is particularly important when a smelter releases also converter gas to a chimney due to the lack of customers for sulphuric acid.

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