中南大學
CENTRAL SOUTH UNIVERSITY

Unit 14 copper metallurgy


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School of Metallurgy and Environment

[ˌkælkəˈpaɪraɪt]

A

New words and expressions

- reddish stones n 红色石头
- malleable ['mæliəbl] adj. 可锻的，可塑的
- casting ['kæstɪŋ] n铸造
- bronze [brɒnz] n 青铜
- brass [bræs] n 黄铜
- trough [trɔ:f] n 水槽
- Chalcocite ['kælkəsaɪt]/ n.辉铜矿
- covellite [koʊ'velaɪt] n.铜蓝,靛铜矿
- chalcopyrite [ˌkælkə'paɪraɪt] n.黄铜矿
- Bornite ['bɔ:naɪt] n.斑铜矿
- Cuprite ['kju:praɪt] n.赤铜矿
- Tenorite ['tenəraɪt]/ n.黑铜矿

New words and expressions

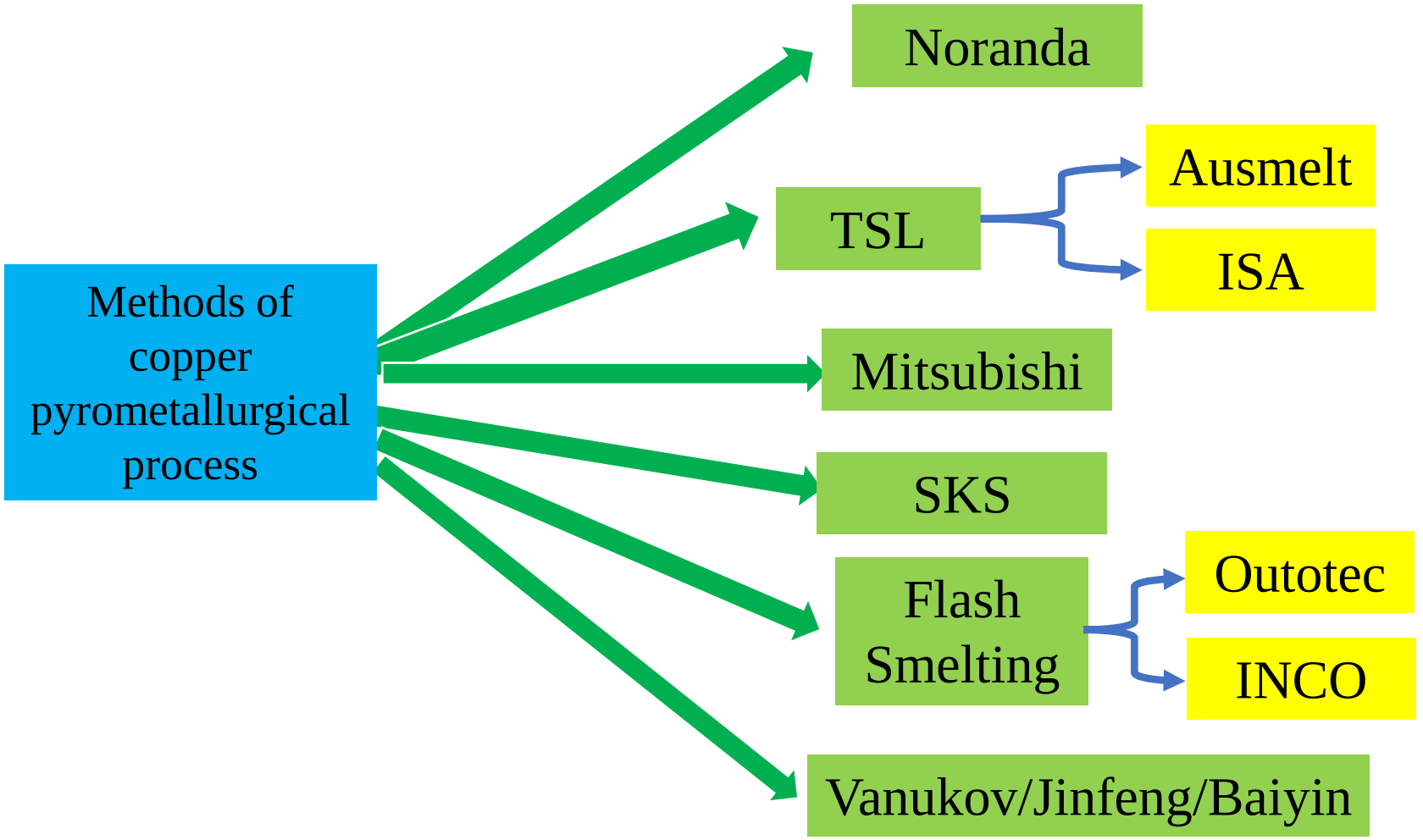
- malachite ['mæləkaɪt] n.孔雀石
- comminution [ˌkɒmə'nju:ʃən] n. 粉碎
- pulverization/ˌpʌlvəraɪ'zeɪʃən/ n. 粉碎；粉化
- boulder ['boʊldər] n. 巨砾；漂砾，大块石头
- Jaw[dʒɔ:] n. 颌；颚
- Gyratory[ˈdʒaɪrəˌtoʊri] adj. 旋转的，回旋的
- Cone [koʊn] n. 圆锥
- Repellent [rəˈpelənt] adj. 防……的
- Hydrophobic [ˌhaɪdrəˈfoʊbɪk] adj. 疏水的;憎水的
- Taphole [ˈtæphoʊl] n. 出渣口，塞孔

New words and expressions

- Siliceous [sɪ'lɪʃəs] flux 硅质熔剂
- Granulate [ˈgrænjəˌleɪt] v. 使成为粒状
- Pneumatically [nu:'mætɪkəlɪ] adv. 由空气作用
- billet坯
- ingot锭
- sheer型材、复合板带
- tough-pitch copper紫铜,韧铜
- Poling ['poʊlɪŋ] n. 还原，除气
- cement copper沉淀铜，泥铜（沉淀置换的铜），渗碳铜
- leachate ['li:tʃeɪt] n. 沥滤产物，浸析液
- settling tank澄清槽

- Copper ore
- Pyrometallurgy process
  - Smelting: the aim is to get matte(50-75% Copper)
    - Flash furnace
  - Converting : to get blister copper(98.5% copper)
  - Anode refining and casting
    - to get anode (99.5% copper)
  - Electrorefining cathode 99.99% copper
- Hydrometallurgy

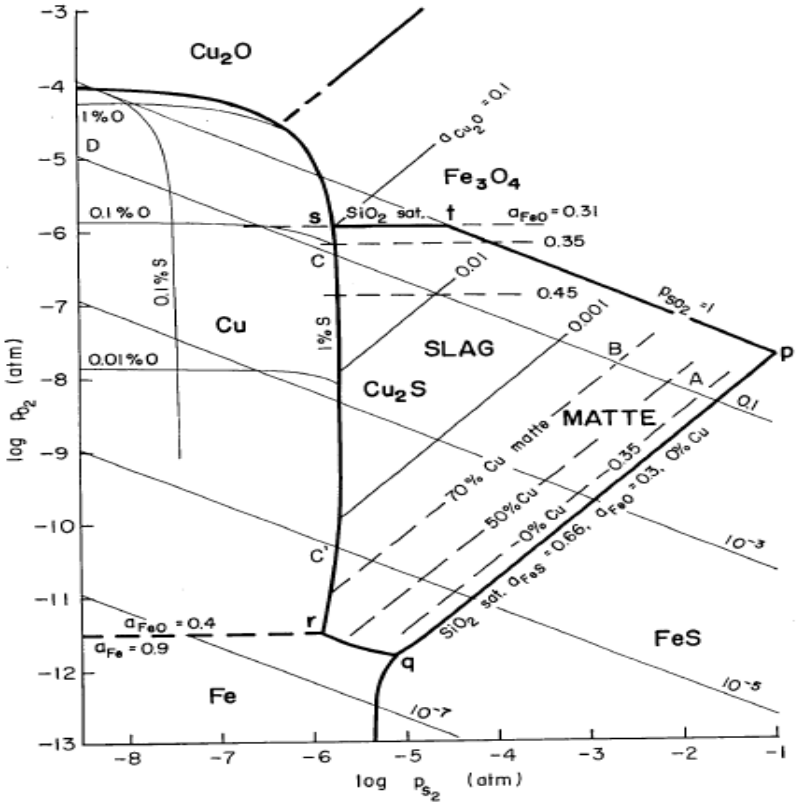
Smelting process



- Noranda/Teniente smelting process诺兰达/特尼恩特法
- Ausmelt/ISA smelting process奥斯麦特/艾萨
- Flash smelting process闪速
- Mitsubishi process三菱
- Oxygen bottom blowing/SKS process氧气底吹

Smelting principle

Flash Smelting technology



Sulfur-oxygen potential diagram for the system Cu-Fe-S-O-SiO2 at 1300℃

Concentrate

Chalcopyrite ($CuFeS_2$)

Matte

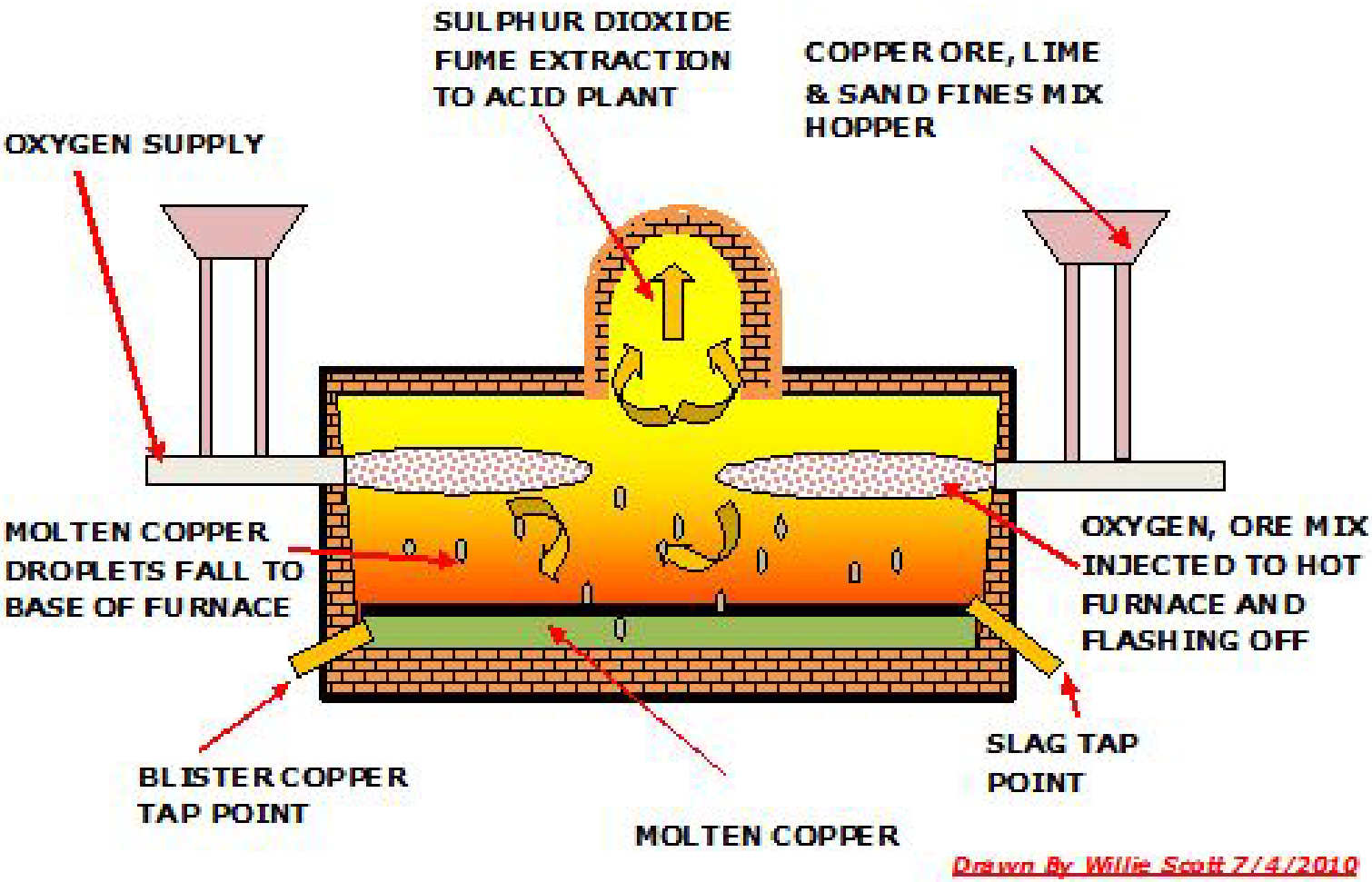
Cu_2S▪FeS

$$CuFeS_2 + O_2 + SiO_2 \rightarrow$$

$$[Cu_2S \blacksquare FeS] + (2\,FeO \blacksquare SiO_2) + SO_2$$

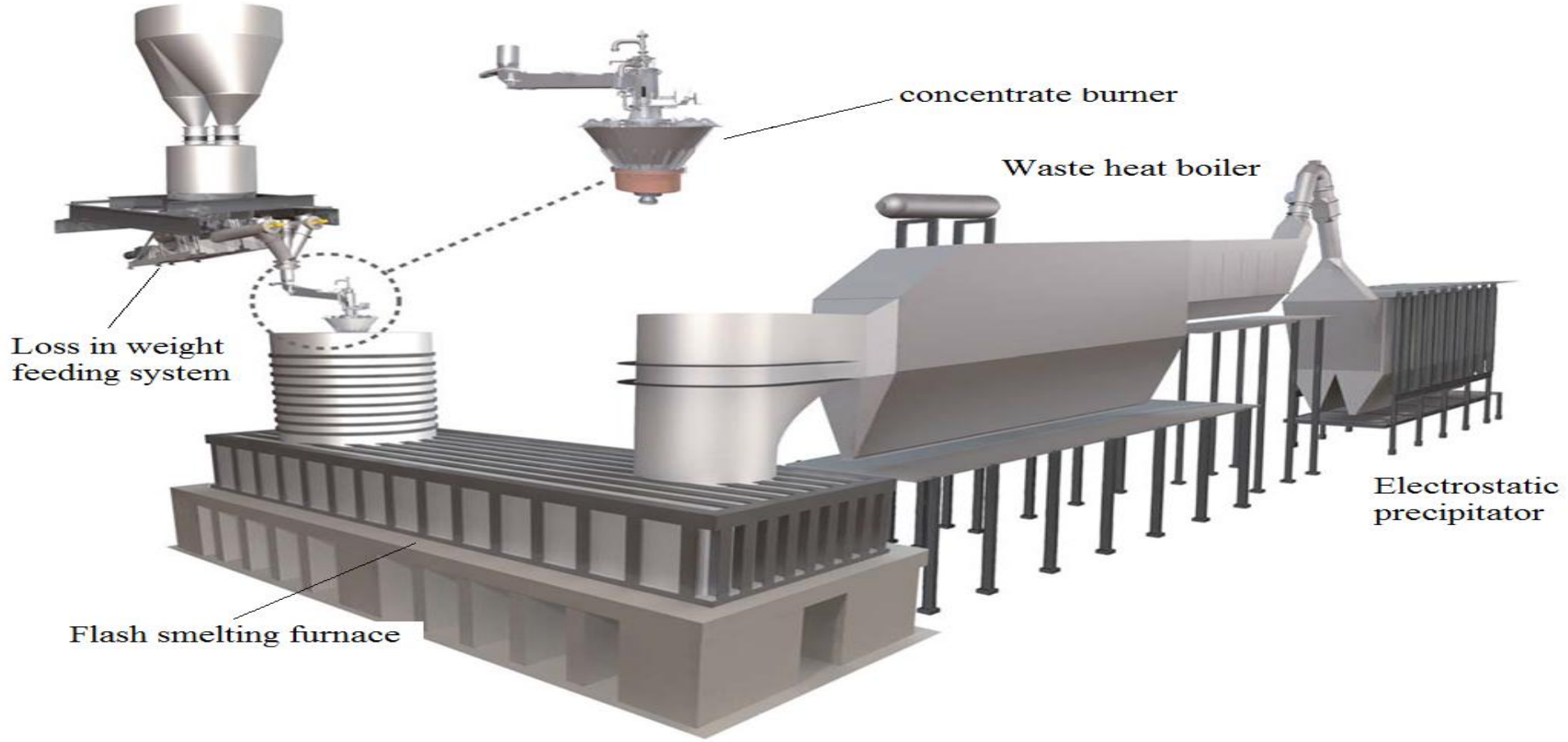
Matte Slag

Smelting principle



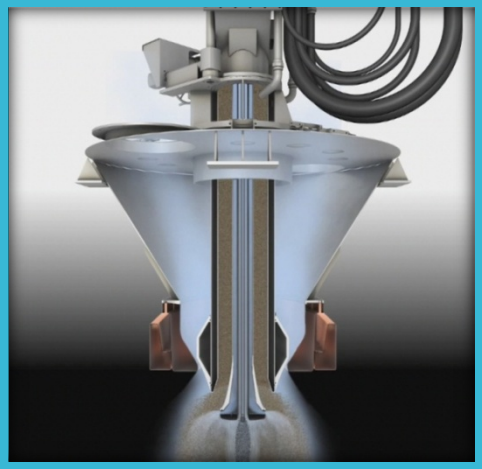
TYPICAL FLASH SMELTING FURNACE (PREHEATING BURNERS OMITTED FOR CLARITY)

2、Flash Smelting



Smelting furnace

Outotec Flash smelting furnace



Concentrate burner

≤300 mesh

≤0.3%

80%

70%

Converting

Matte

Blister copper

(Cu 98.5~99.3%)

slag making stage

$2FeS+3O_2=2FeO+SO_2$

$2\ FeO+\ SiO_2=2\ FeO\cdot SiO_2$

copper making stage

$2Cu_2S+3O_2=2Cu_2O+2SO_2$

$Cu_2S+\ 2Cu_2O=6Cu+SO_2$

- Copper ore
  - Copper is one of the most important nonferrous metals. Its usefulness is accounted for by its combination of chemical, physical, electrical and mechanical properties and is fairly abundant supply. Copper is one of the first metals to have been used by man.

- Natural occurrence
  - sulfide ores: chalcocite辉铜矿, Cu_2S; covellite铜蓝, CuS; chalcopyrite黄铜矿, $CuFeS_2$; and bornite斑铜矿, Cu_5FeS_4;
  - Oxidized ores: cuprite赤铜矿, Cu_2O; tenorite黑铜矿, CuO; and malachite孔雀石, $CuCO_3Cu(OH)_2$ Native copper, once widespread in the United States, is now mined in quantity only in Michigan。
- The grade of ore used for copper production has been going steadily downward as the richer ores have become exhausted and the demand for copper has grown.

Copper ore grade

- The average ore in the United States contains less than 1% copper, but the average is higher in other countries.
- There are vast amounts of copper in the ground, available for future use if ores of still lower grades are utilized, and there is no prospect of exhaustion for a long time to come. At the same time, the use of lower-grade ore increases production costs.

Current production status

- About 80% of the world's copper from ore is produced by pyrometallurgy of sulfide ores. The other 20% is produced by heap leaching / solvent extraction /electrowinning of 'oxide' and chalcocite ores. There are many variations in the production processes and improvements are constantly being made. The main process of copper production is shown in (Fig. 14-1)
- Pyrometallurgical processes employ high temperature chemical reactions to extract copper from its ores and concentrates. These processes generally are used with copper sulfides and, in some cases, high-grade oxides.

80% of the world's copper……, the other 20%....

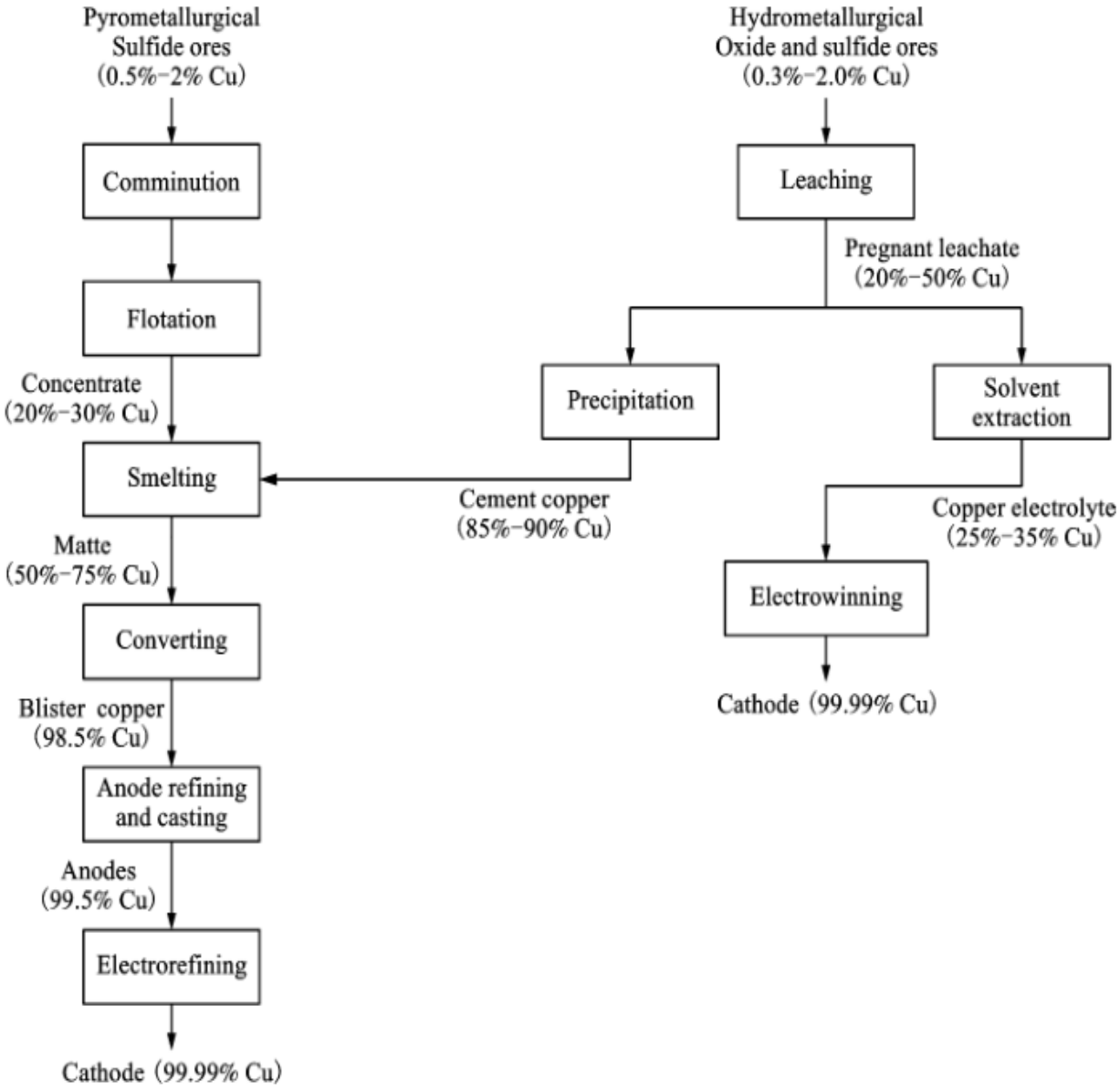


Fig. 14–1 Flowsheets for copper production

smelting

- The basis of the process is that reactions between copper, oxide and iron sulfide in the molten charge have negative free-energy changes, forming copper sulfide and iron oxide.
- With excess iron sulfide, the copper sulfide forms a molten solution called copper matte. The iron oxide formed in the reactions, together with that added as flux, unites with silica in the ore to form a slag.

$$CuFeS_2 + O_2 + SiO_2 \rightarrow [Cu_2S \cdot FeS] + (2\,FeO \cdot SiO_2) + SO_2$$

Matte Slag

Concentrate

Matte

Chalcopyrite ($CuFeS_2$)

$Cu_2S \cdot FeS$

The reactions that take place in the smelting process can be divided into four categories:

(a) Decomposition of sulfide ores

$$2FeS_2 \longrightarrow FeS + S_2 \quad (14-1)$$

$$2CuFeS_2 \longrightarrow Cu_2S + 2FeS + \frac{1}{2}S_2 \quad (14-2)$$

(b) Oxidation of sulfides

$$2CuFeS_2 + \frac{5}{2}O_2 = Cu_2S \cdot FeS + FeO + 2SO_2 \quad (14-3)$$

$$2FeS_2 + \frac{11}{2}O_2 = Fe_2O_3 + 4SO_2 \quad (14-4)$$

$$3FeS_2 + 8O_2 = Fe_3O_4 + 6SO_2 \quad (14-5)$$

$$2CuS + O_2 = Cu_2S + SO_2 \quad (14-6)$$

$$2FeS + 3O_2 = 2FeO + 2SO_2 \quad (14-7)$$

$$2Cu_2S + 3O_2 = 2Cu_2O + 2SO_2 \quad (14-8)$$

(c) Matte smelting

$$FeS + Cu_2O = FeO + Cu_2S \quad (14-9)$$

(d) Slag-making reaction

$$2FeO + SiO_2 = 2FeO \cdot SiO_2 \quad (14-10)$$

smelting

- To accelerate the chemical reaction rate, flash smelting technology are developed in recent decades.
- In flash furnaces, concentrates are blown, together with oxygen or an air/oxygen mixture, into a hot furnace. The sulfide particles in the concentrates react quickly with the oxygen and combustion is extremely rapid.
- This produces enough heat to provide a large proportion of the thermal energy needed for smelting. As a result, flash furnaces have relatively low fuel costs.

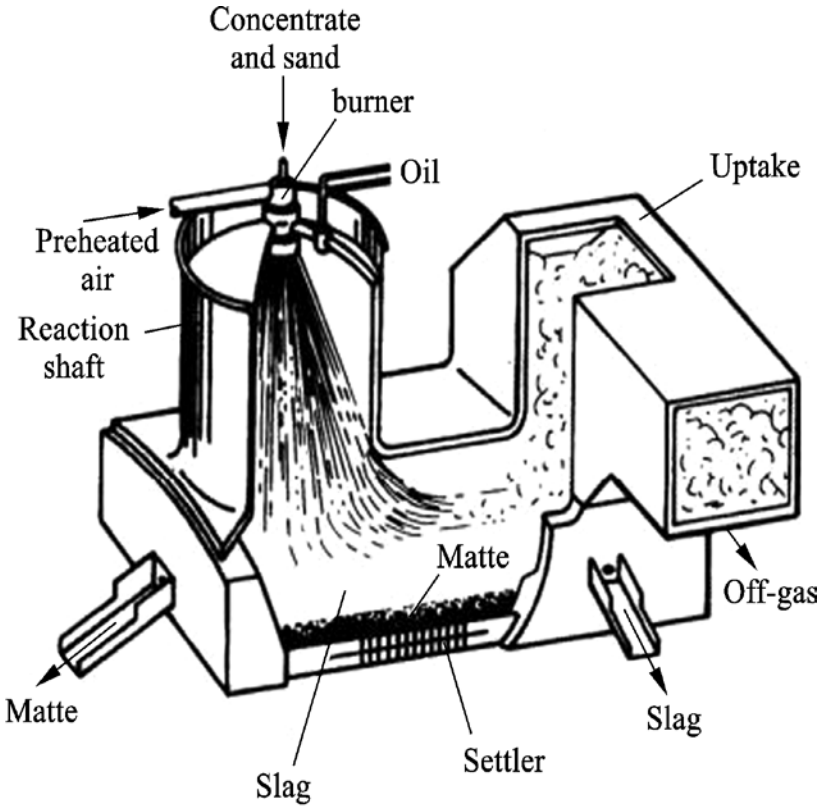
together with: 相当于 and

smelting

- Their production rates also are high due to the rapid rate at which the mineral particles are heated, and the matte is relatively rich (50% to 75% copper).
- Further, their waste gases are rich in SO_2, permitting economic pollution control. The principal disadvantage of flash furnaces is the high copper content of the slag (around 0.7% to 1.0% copper).
- This means that the furnaces cannot be used efficiently to recover copper from converter slag, and in some cases, the smelter slag must be recycled through the comminution and beneficiation plants.

smelting

- Outokumpu flash smelting accounts for more than half of Cu matte smelting(Fig.14-2). It is also used in two locations for direct-to-copper smelting and in one location for continuous converting. It blows oxygen, air, dried concentrate, flux and particulate recycle materials as a well-dispersed mixture into a hot reaction shaft.
- Smelting reactions are extremely fast under these conditions. Outokumpu flash furnaces smelt up to 3000 tons of new concentrate per day.



smelting

- Modern Outokumpu flash furnaces operate with high oxygen blast and very little hydrocarbon fuel. Most of the energy for heating and melting comes from FeS_2. Outokumpu flash furnaces are operated under automatic control to give constant temperature, constant composition products at a rapid rate, and with minimum energy consumption. Wide adoption of Outokumpu flash smelting is due to its efficient capture of SO_2, its rapid production rate and its small energy requirement. Its only limitation is its inability to smelt scrap.

Why?

句型：Furnaces are operated under …control … and with ….consumption

Converting

- The matte is taken to a converter, in which air is blown through the molten matte to oxidize the iron chiefly to FeO, which is slagged by addition of a siliceous flux.
- The sulfur in the matte is oxidized to SO_2 and passes off in the gases, leaving copper in the converter.
- When cast, the copper forms cakes with a surface roughened and blistered by the escape of gases during freezing, and hence is called blister copper with 98-99%Cu. The most common device is the P–S converter and flash converting.

Converting

- The Kennecott–Outokumpu flash converting process was commissioned during late 1995 at the Utah copper smelter.
- Matte is granulated 造粒 with high-pressure water and then conveyed to storage. After granulation the solidified matte has the appearance of sand particles ranging from 0.2 to 2 mm in size and with 4~8% moisture. The ground matte is pneumatically conveyed to the flash converting furnace which is fitted with more extensive water and air cooling than the first stage of flash smelting.
- The customized unit continuously converts the matte into a low sulfur blister copper upon employing a lime-based flux to form slag.

Fire refining

- The blister copper is next partly refined in a furnace and cast into anodes. It may be poured in molten form into the anode furnace, or it may be cast into cake which is charged to the furnace and remelted.
- An oxidation refining takes place in the furnace, assisted by introduction of a small amount of air below the surface of the molten copper.
- Little or no flux is required. Impurities whose oxides have a more negative free energy of formation than copper are oxidized and removed as slag or in the gases. The copper is cast into anodes containing about 99.0-99.3% Cu.

Occur, happen, take place

- 三者都表示“发生”，都是不及物动词.
- happen指“偶然发生”时，主语为“事”；当主语是“人”时，意为“碰巧”。
- occur 指“发生”时可与 happen 换用，但后接to sb／sth时,两者含义不同：happen to sb／sth 指不好的事情发生在某人（物）身上；occur to sb／sth 指“某种思想等呈现于某人的知觉中”
- Take place 表示“发生”,可与 happen 或occur换用，但其后面一般不接 to sb／sth结构；指必然会发生的事情时，多用 take place；此外take place 还可表示“举行某种活动”.如：

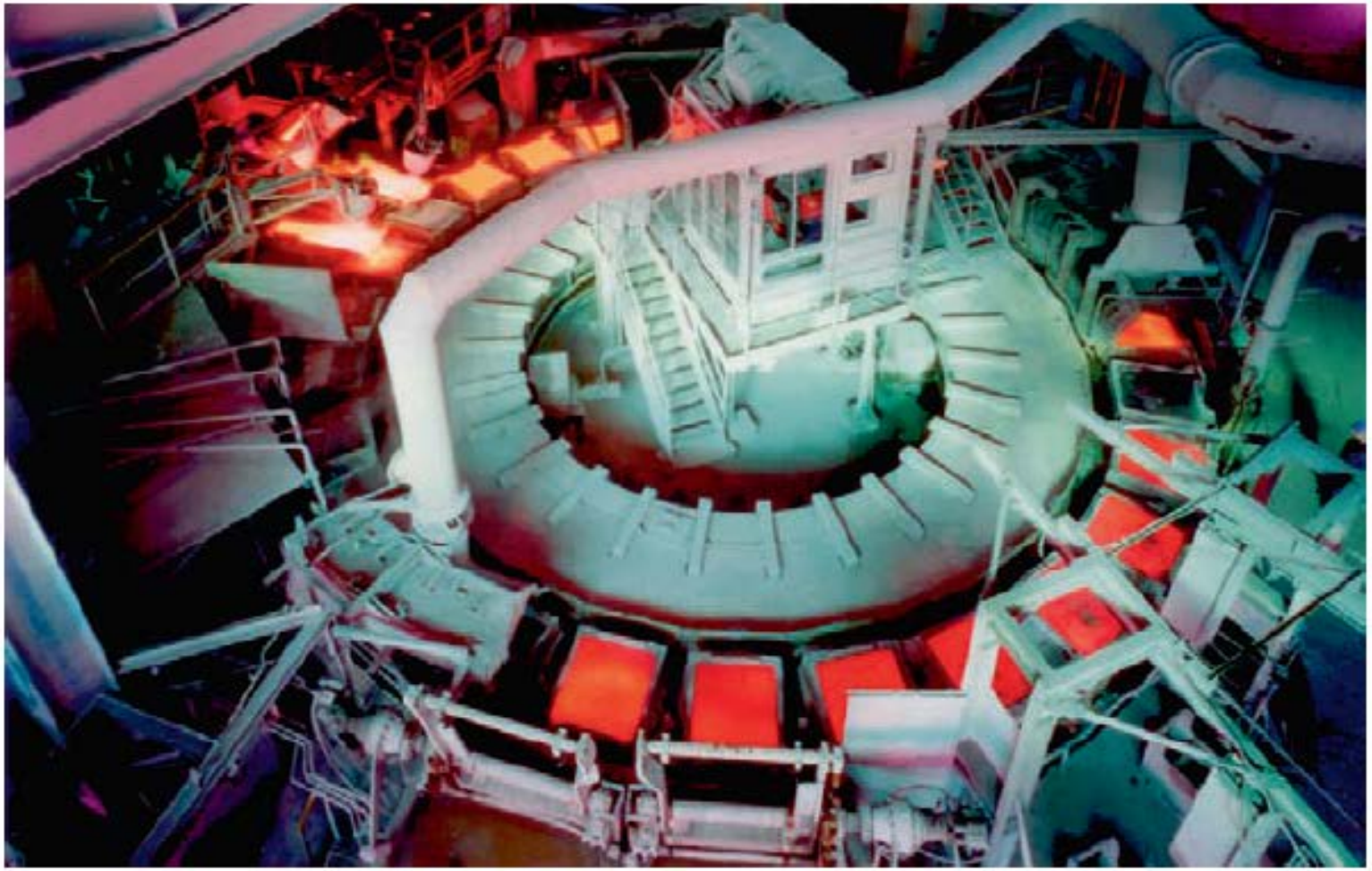
  He happened to know the place． 他碰巧知道那个地方.

  When did the earthquake occur／happen?地震是什么时候发生的?

  Didn’t it occur to you to phone them about it?你难道就没想过给他们打个电话?

  Has anything happened to him?他出什么事了吗?

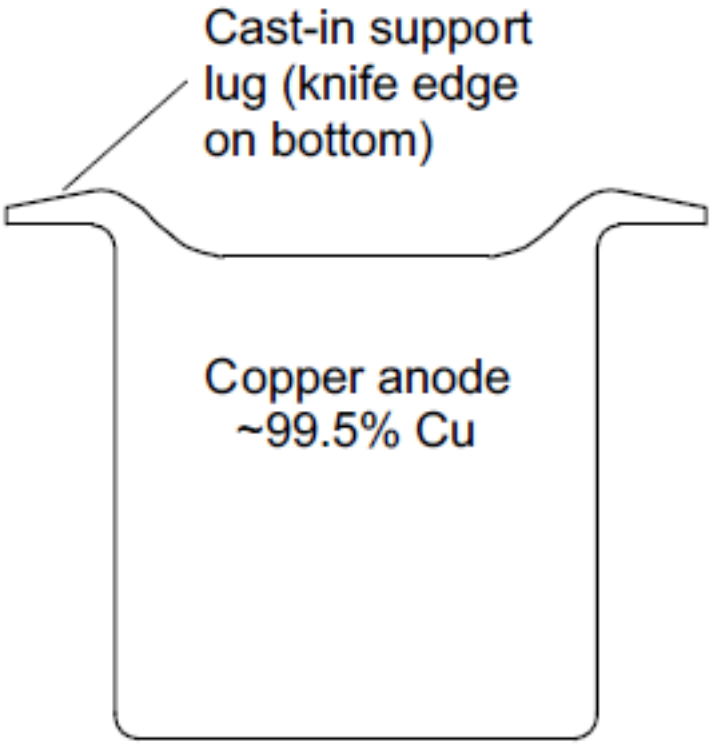
  In 1919，the May 4th Movement took place in China．一九一九年,中国发生了五四运动.



electrorefining

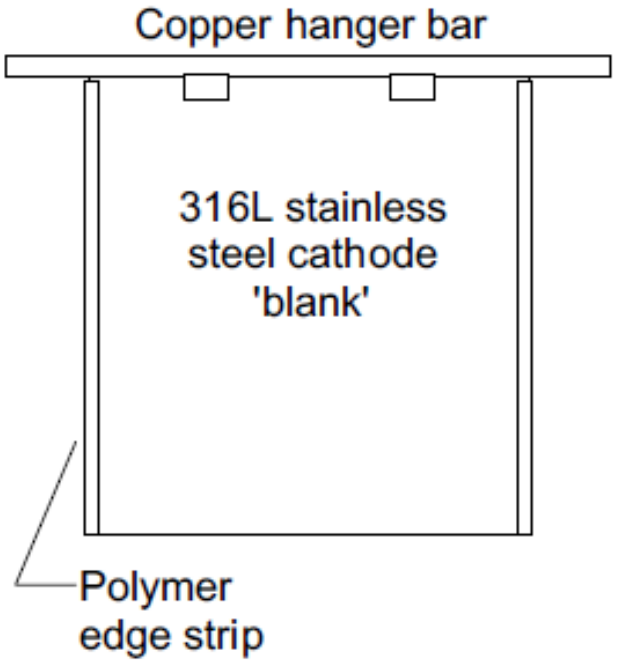
- The anodes are hung in electrolytic tanks, spaced alternately with cathodes, in an electrolyte of copper sulfate and free sulfuric acid, contaminated with soluble impurities.
- Insoluble impurities, in the main those below copper in the electrochemical series of metals, fall to the bottom of the tank; these include gold, silver, selenium, and tellurium.

anode



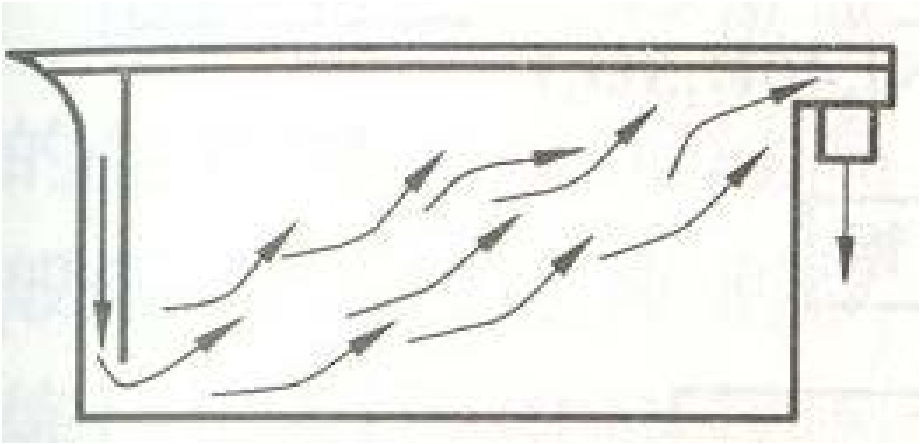
Lug:耳状物

cathode

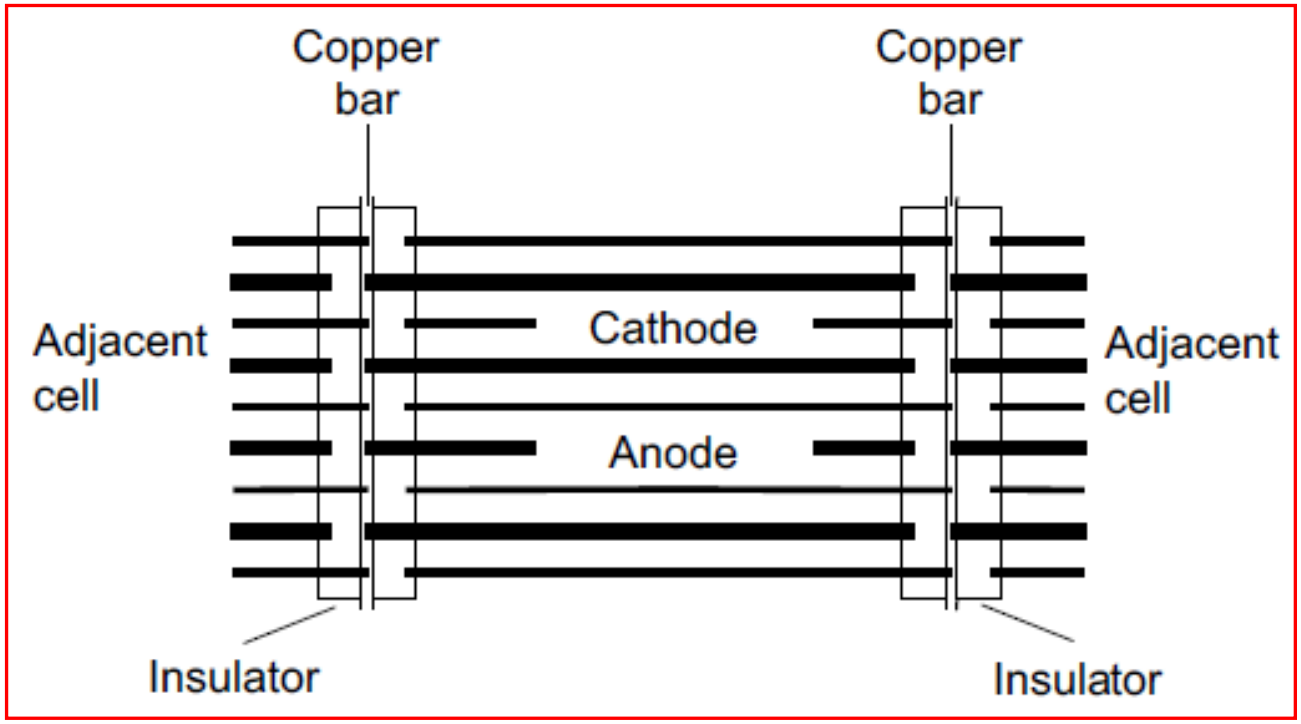


Strip：条

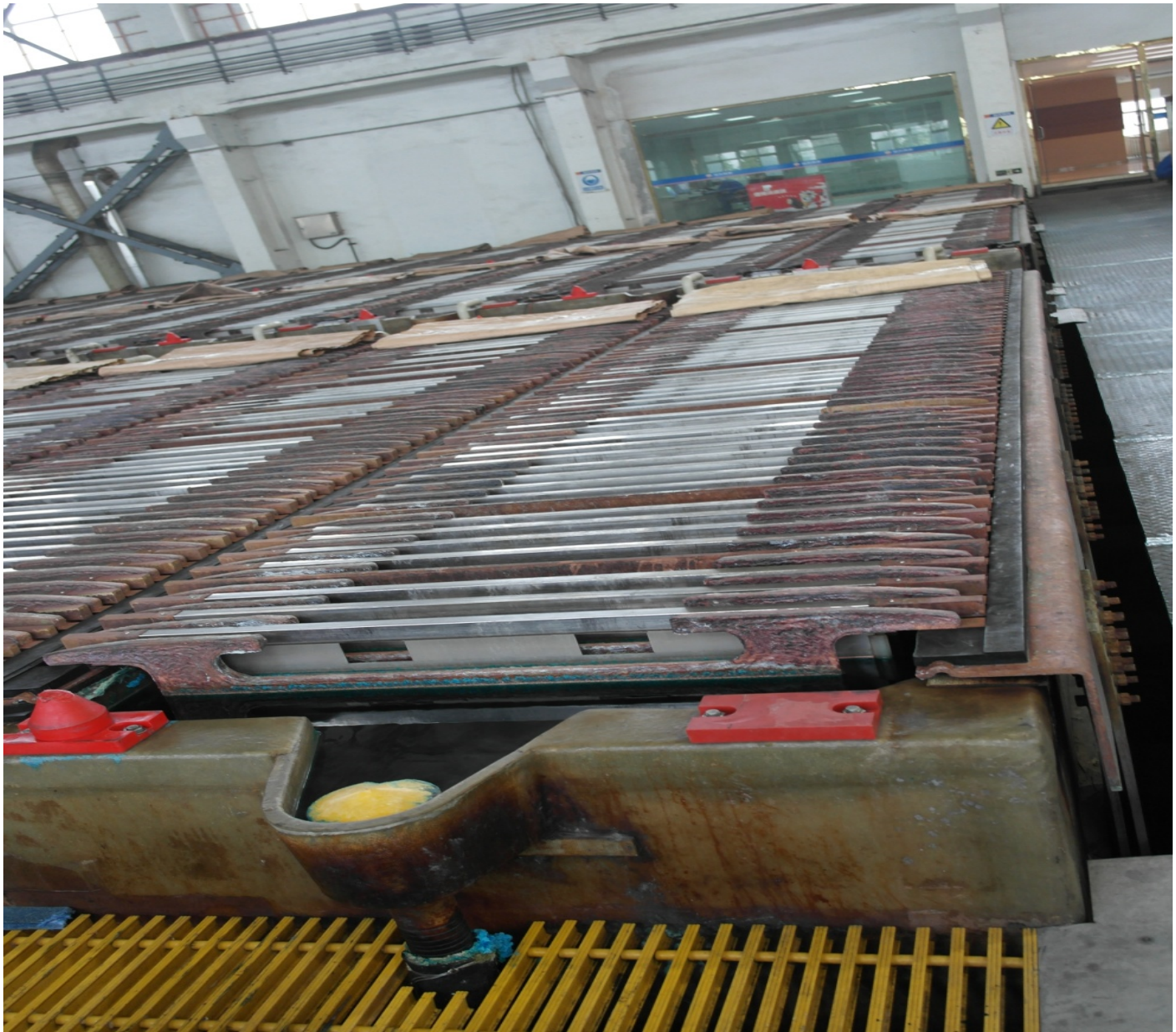
Electrolytic tank



Electrode arrangement



Electrolysis in practice



electrorefining

- Soluble impurities, in the main those above copper in the electrochemical series, enter the electrolyte and do not plate out at the cathode.
- These are chiefly nickel and arsenic, together with smaller amounts of other elements.
- Some of the impurities form insoluble compounds. Thus the copper is free of nearly all impurities, whereas a furnace-refining process can remove only those more easily oxidized than copper.
- The cathodes are usually remelted for casting into shapes such as wire, bars, cakes, billets or ingots.
- Some of the cathodes are sold without remelting, but the shapes are required for fabrication into such forms as rods, wire, sheet and tubes.

Together with 的用法

- together with 译为：和，加之，带有，总和；together with后面要加宾语，因为with是一个介词，后面需要有成分。
- together with是一个介词短语，在句子中起到修饰的作用，谓语动词的变化要与主语的人称与数保持一致。
- 当句子中主语后面存在as well as与…一样， more than超过，together with带有等以上任意一词组时，谓语动词要与最前面的主语保持一致。**即所谓的“就远原则”**
  - eg: He, as well as me, gets some letters from parents.他和我都收到了一些家书。
  - I, together with Jack, want to go to the zoo.我和杰克都想去公园。

Hydrometallurgical process

- A considerable amount of copper is produced by hydrometallurgy. The ore is leached without being concentrated, dilute sulfuric acid as the solvent is most often used. The process is applied chiefly to oxidize ores. A further limitation of leaching is that the solvents employed do not dissolve gold or silver.
- After leaching, it is necessary to recover the copper from the leaching solution.

Cementation, solvent extraction

- One method of precipitating the copper from the leaching solution is to pass it over scrap iron or sponge iron. Copper is replaced in the solution by iron and precipitates as so-called cement copper. In this case, the precipitated copper is not pure and must be refined.
- Another method is solvent extraction, an organic chemical that dissolves copper but not impurity metals is mixed with the pregnant leachate from the leaching solution.

Solvent extraction

- The copper-loaded organic solution is separated from the leachate in a settling tank. Sulfuric acid is then added to the pregnant organic mixture, which strips the copper into an electrolytic solution for electrowinning. Solvent extraction is advantageous in that the electrolyte has almost no impurities and few environmental problems. Solvent extraction also makes relatively efficient use of the various solutions: the spent leachate is returned to the leaching operation, the barren solvent is recycled to the pregnant leachate, and the spent electrolyte to the loaded solvent.

省略了 is recycled

process	flowsheet	ore
pyrometallurgy	Smelting→converting→fire refining→electrorefining→copper cathode	Sulfide ore, high-grade ore
hydrometallurgy	1)Leaching→cementation→smelting 2)leaching→solvent extraction→electrowinning	Oxide ore, low-grade ore

- Write a summary of the text
- Compare with different smelting processes

THANKS

End

lecturer: Xiyun Yang

School of Metallurgy and Environment