## 1. Title:

Process description of Aurubis AG, Luenen plant to inform customers, suppliers and external auditors

## 2. Purpose:

This works` description has been compiled for customers who perform their own audits of processes and work procedures within the framework of DIN EN ISO 9001, DIN EN ISO 14001 and according to EU regulation No. 1221/2009 (EMAS) or any appropriate audit scheme for waste management and notifications of EC 1013/2006 Art. 4 and 5.

## 3. Scope:

Aurubis AG, 44532 Luenen Germany

## 4. Terms:

Special terms are explained in detail under item 6.

## 5. Responsibilities:

The IMS officer and the Supply Chain Management (Recycling Raw Materials Procurement) are responsible for compiling and updating this description.

## 6. Process description

### 1. General

Aurubis AG Luenen has always been a copper recycling plant. The recovery of copper and its by-products from scrap and other residues has been the core activity throughout the company history.

The entrepreneur Kayser erected the company's first smelter in Berlin in 1861. In 1916 the branch in Luenen started production. In 1945 the Berlin works was lost and the Luenen works was then continuously expanded into the largest secondary copper smelter worldwide.

Norddeutsche Affinerie AG acquired the majority shareholding in Hüttenwerke Kayser AG at the turn of the year 1999/2000 and in 2004 Hüttenwerke Kayser was merged with Norddeutsche Affinerie AG.

Norddeutsche Affinerie AG has been renamed Aurubis AG with effect from 1 April 2009.

Now the works is part of Aurubis business unit operations. The Supply Chain Management (Recycling Raw Materials Procurement) ensures that all Aurubis sites are supplied with secondary raw materials.

### 1.1 Purpose of the plant

Aurubis AG operates a secondary copper smelter at Luenen site, in which copper residues of various origins are processed in a multi-stage recycling process into high-grade copper and by-products. The by-metals contained in the secondary raw materials (e.g. copper scrap, copper alloy scrap, slag, skimming's, e-scrap) such as zinc, tin, lead, nickel and precious metals are likewise recovered or enriched for subsequent recycling processes.

The pyrometallurgical process stages are currently carried out in the Kayser Recycling System (KRS) as well as in the smelter's anode furnaces. The hydrometallurgical process stages are performed in the refining tankhouse and in the electrolyte treatment plant. The most important attendant facilities are the material preparation plant, the sampling plants, the workshops, storage halls and storage yards.

Aurubis AG Luenen processes approx. 400,000 tonnes of copper-bearing materials into about 200,000 tonnes of high-purity copper each year. 20,000 tonnes of zinc-bearing KRS oxide, 160,000 tonnes of slag granules (iron silicate sand) and 4,500 tonnes of lead/tin alloy (Sn35Pb65) are produced and marketed as by-products of the smelter operations. Copper is produced in form of cathodes in the tankhouse. By-products are extracted there as well in the electrolyte treatment section, in the form of 3,000 tonnes of anode slime (precious metal concentrate) for further treatment at the Aurubis Hamburg site and 4,000 tonnes nickel sulphate which is currently marketed as crude sulphate.
The plan expands on a size of 3,400,000 sq feet.

### 1.2 Permit situation

The whole works is licensed as a plant for the production of non-ferrous crude metals in accordance with 4. BImSchV, No. 3.3, column 1.

The original permit was issued in 1914 by the local government of Arnsberg in accordance with the industrial code under the file number B.A.I.C.XVa 93/13. Even then, the works was designed for the production of copper from copper-bearing metal recycling materials. Works expansions, modernisation, etc., since then have been approved as significant changes in terms of today's § 16 BImSchG.

The Arnsberg local government is the licensing authority.

The following licences have been awarded as regards current plant and equipment:

| File no. | Date | Contents |
|---|---|---|
| 56.8851.3.2 – G 33/92 and | 15.07.1993<br>12.11.1993 | Tankhouse, expansion and modification to permanent cathodes |
| 56.8851.3.2 – G 30/93 | 31.03.1994 | Anode furnace V |
| 56.8851.3.2 – G 26/98 | 1.03.1999 | Updating feed materials |
| 56.8851.3.2 – G 03/99 | 14.04.1999 | Tankhouse, expansion to 185,000 tpa |
| 56.8851.3.2 – G 08/01 | 29.06.2001 | Leaching plant / decopperising various changes |
| 56.8851.3.3 – G 45/01 T 3 | 21.03.2002 | KRS operation |
| 56.8851.3.3 – G 13/03 | 26.09.2003 | KRS – E-scrap |
| 56.8851.3.3 – G 14/05 | 27.07.2005 | Material preparation plant |
| 56.8851.3.3 – G 25/06 | 12.10.2006 | E-scrap sampling plant |
| 56.8851.3.3 – G 26/06 | 19.02.2007 | KRS–E-scrap, 20,000 tpa. |
| 56.8851.3.3 – G 57/06 | 16.03.2007 | Tank house, capacity 210,000 tpa |
| 53.0133/08/0303.1-Fr | 27.05.2009 | Storage hall 4 |
| 53.0136/08/0303.1-Fr | 30.06.2009 | New plant entrance |
| 53.066/09/0302.1-Fr | 30.10.2009 | Storage hall 5 and 5A |
| 53.049/10/0303.1-Fr | 03.11.2010 | Replacement of anode furnace filter 2 |
| 53.0119/09/0303.1-Fr | 04.04.2011 | KRS-Plus (TBRC) |

| File no. | Date | Contents |
|---|---|---|
| 53.0090/10/0303.1-Fr | 16.05.2011 | Storage area south |
| 53.025/12/0303.1-Fr | 24.09.2012 | Sampling furnace 4 |
| 53.0154/12/0303.1-Fr | 16.01.2013 | Modification exhaust ventilation – Anode furnace area |
| 53.0157/12/0303.1-Fr | 08.032013 | Replacement and capacity expansion Smelter auxiliary filter |
| 53.114/12/0303.1.-Fr | 10.04.2013 | Optimization of steam- and water infrastructure |
| 53.148/12/0303.1.Fr | 25.10. 2013 | rainwater retention |
| 53.108/13/0303.1-Fr | 21.11.2014 | Modernization Tankhouse |
| 53.073/14/3.3-Fr | 08.02.2015 | Optimisation of nickel recovery anode furnace |
| 53.0043/15/3.3-Fr. | 18.05.2016 | Update Waste catalog |
| 900-0877505-0001/ IBG-0001-G 11/22 Fr | 28.09.2022 | Night operation screening fraction MV-ZS |
| 900-0877505-0001/ IBG-0004-G 51/22 Fr | 11.10.2022 | New sampling filter including hall extraction |

The Luenen Recycling Process works according to R 4, Recovery of metals and metal components. The official disposer-No. for the plant is E 97897118.

### 1.3 Integrated Management System (IMS)

The IMS system has been introduced and applied for the entire works of Aurubis AG Luenen, technical processes and services. The IMS system consists of a quality management in accordance with DIN EN ISO 9001:2015 and an environmental management system in accordance with EN ISO 14001:2015 and EU ordinance 1221/2009 (EMAS). Occupational health and safety protection as well as risk

management and AEO (Authorized Economic Operator) are central tasks of Aurubis AG. In addition, in 2013 the certification according to DIN EN ISO 50001 energy management was completed.
At the moment, the Aurubis Luenen plant is certified as end-processor of electronic waste (E-scrap) according to the EERA-Standard. This certificate will be transfered into the WEEELABEX-Standard in 2018. Furthermore, the Material preparation plant (MZ-ZS) is certified as a disposal specialist (“Entsorgungsfachbetrieb”).

The function of the IMS system is

- to document that processes, procedures and products meet the requirements in all phases,
- to avoid mistakes during planning, controlling, production and every other processes,
- to detect potential errors as early as possible and to take measures to prevent them.

## 2. Process description

### 2.1. Principles of operation

Since the KRS achieved regular operation at the end of 2003, the smelter operations of Aurubis AG Luenen concentrated on this plant sector as well as on the connected anode furnace plant.

In June 2011 the smelter expansion project KRS Plus was commissioned. An additional TBRC furnace (Top Blowing Rotary converter) enables to process more copper low-grade raw materials and to optimize the metals recovery rates in the sense of resource and energy efficiency.

As a result of the interplay between these installations, the copper contained in the secondary raw materials is enriched and produced as electrolytic copper in the form of cathodes. The by-products in the various steps are separated and processed into saleable products. Production-specific waste is almost completely eliminated in this way.

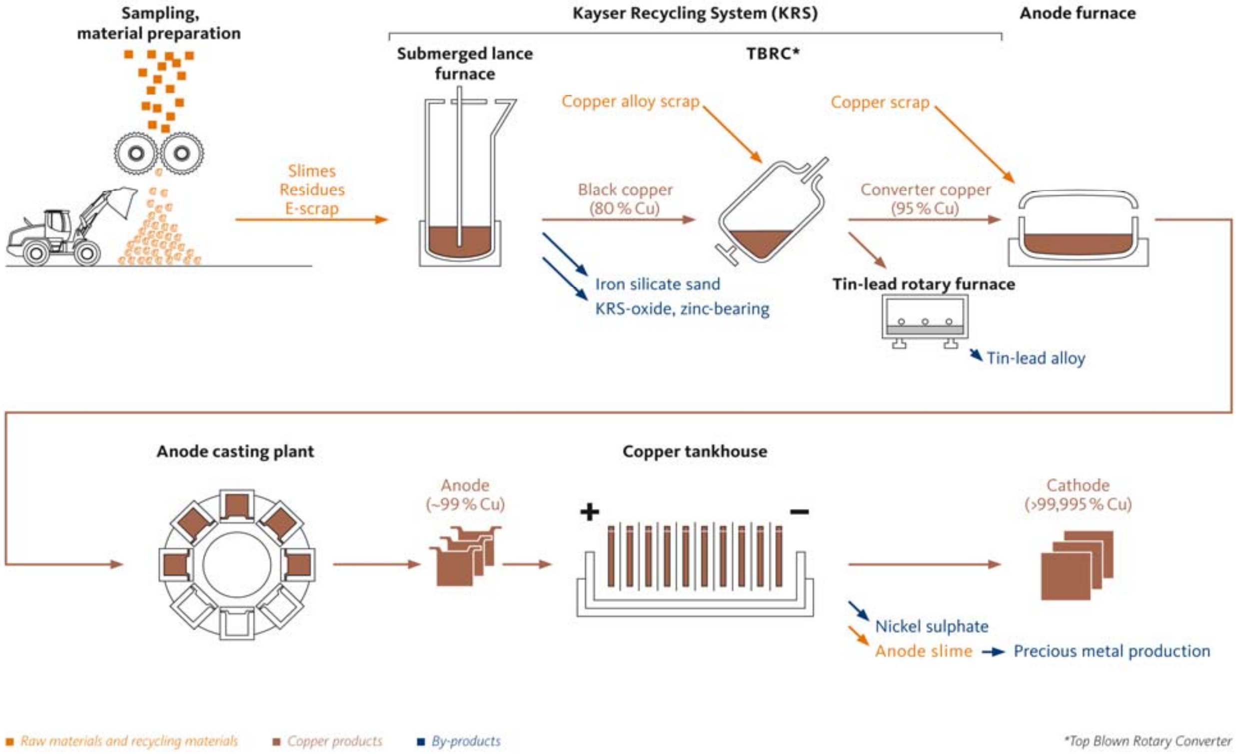


Figure 1 **Flowsheet Aurubis AG Luenen**

Secondary raw materials with low copper contents, oxidic materials and copper/iron materials (including electronic scrap) are reduction-melted in the KRS's melting phase with addition of slag formers. The furnace can be described as submerged lance furnace. This results in a so-called “black copper” with 75 – 85 % Cu as well as an iron silicate slag low in copper content. So-called zinc bearing KRS oxide arises as a by-product which is extracted from the off-gas by means of filter plants.

The black copper is tapped and converted in an adjoining TBRC (Top Blowing Rotary Furnace) in the converting stage together with alloy scrap. Crude lead/tin alloy is produced in the lead/tin furnace which is then processed into marketable lead/tin alloy in several stages.

The converter copper is initially stored temporarily in the holding furnace and then processed together with copper scrap in the anode furnaces. Both the anode furnace flue dust and the anode furnace slag are returned to the KRS.

The copper is cast in moulds on two casting wheels; the resultant sheets are used as anodes in the refining tankhouse. There, the electrolysis process results in the main product of copper cathodes. The by-products of anode slime, copper sulphate and crude nickel sulphate are acquired in the tankhouse attendant facilities.

## 2.2 Material handling

All vehicles that enter the works pass a lock beforehand with radioactivity detectors. In case of an anormaly, the material is inspected in detail after corresponding instructions and, if necessary, excluded from further processing at the works.

The delivery papers are then checked and processed, the weight determined and the material is inspected visually. The driver is subsequently shown a storage area where the material can be unloaded. The material is stored under conditions, which avoid or at least minimize the environmental impact. Dusty materials, slimes and other material which could cause emissions are unloaded and stored in halls. Outside storage areas use sprinklers to avoid dust formation and have concrete surfaces for soil protection.

### 2.2.1 Material preparation plant

A variety of materials is crushed and fractionated in the material preparation plant, such as de-polluted end-of-life electrical appliances, lumpy sheets, etc.

To enable this, the materials are loaded on a conveyor belt by a digger which leads to the crusher. Then the crushed material undergoes a process chain of several separations in which the dusty fraction is removed / collected and the heavy material subsequently passes through various fractionating devices in which the different non-ferrous metal fractions, iron, plastics and aluminium are separated. Aluminum and plastic fractions are further processed by external operators.

The dust from the crushers enclosure, the pneumatic separator and the sieve drums as well as various transfer points is collected by sucktion and sent to a filter plant. The filtered air is then released via a stack.

### 2.2.2 Sampling Department

The Sampling department has the task of taking samples of raw materials received as required, which are prepared for the analytical determination in our laboratories.

Representative samples of the materials are taken first, if necessary the samples are prepared, e.g. crushed (precrusher, pan grinder, etc.) or packed. Subsequently, they can, for instance, be made homogeneous by melting in a crucible furnace.

Six furnaces are available with a respective holding capacity from 5 (up) to 1,500 kg, heated with oil or electricity (inductive).

For samples which are to be melted, the empty, cleaned crucible is filled with the respective material. In addition, auxiliaries (such as borax, aluminium, iron, pyrite) can also be added depending on the type of the material to be sampled. After a homogeneous melt has been produced, the crucible content is cast in refractory or cast iron moulds.

All the feed material listed in the smelter’s license can be sampled. For sampling printed circuit boards/electronic scrap, Aurubis AG operates two separate facilities, one at the Luenen site and another at the Hamburg site.

In those devices complete deliveries of printed circuit boards are crushed in three steps down to 20 mm. Finally a homogenised and representative sample of the entire material is extracted for further mechanical and pyrometallurgical steps to determine copper and precious metals contents.

## 2.3 Smelter operations

### 2.3.1. Kayser Recycling System

#### 2.3.1.1. Raw materials composition and KRS (submerged lance smelting)

Before the first smelting step (reducing conditions) the materials are mixed in parcels in accordance with the instructions given. For this purpose, there are designated areas in the hall where the materials are piled in layers (on top of each other). A shovel dozer is used to achieve a sufficient mixture by taking corresponding amounts from the finished beds.

Each feed hopper has a discharge device and a weighing device. Other feed hoppers are filled with coal and additives (lime additive, silicate additive).

In addition two bunkers provide alloy scrap and iron additives.

After moistening, fine-grained, dusty materials are treated in the agglomeration plant in such a way that small pellets are formed to improve the charging process (by avoiding dusting during charging). This material blend is transferred to the furnace feed hoppers.

The input material is fed via a belt conveyor gallery from the blending hall. The material is fed into the KRS (submerged lance) furnace via a vibrating pan feeder which is mounted on a conveying and tipping facility.

The heating and addition of fuel, oxygen and air is performed by a lance system. The process is controlled to operate under reducing conditions. The KRS submerged lance furnace has a permit to smelt up to 350,000 tpa. of input materials.

Products of the furnace are a black copper (alloy) (75 to 85 % Cu), granulated slag with very low metals contents, sold as iron silicat sand and a zinc bearing flue dust called KRS Oxide (approx. 50% Zn).

#### 2.3.1.2 TBRC furnace

In June 2011 the KRS-System was expanded by a TBRC (Top Blown Rotary Furnace). The TBRC furnace system consists of a rotary furnace, a holding furnace, a storage hall and a 300,000 m³/h filter system for the process off-gases.

The black-copper metal produced form the KRS (submerged lance) furnace with a copper content of 75 – 85 % is tapped batchwise into the TBRC. In an addition with alloy scrap and fluxes the batch is converted which means to be refined under oxidizing conditions. In this step the copper metal is enriched to approx. 95 % copper content. By-metals like lead and tin are accumulated concentrated in a slag.

#### 2.3.1.3 Lead/tin alloy production

In the lead/tin alloy furnace, crude lead/tin alloy is produced from the converter slag as well as from tin-bearing and lead-bearing recycling materials in a multi-stage metallurgical process. A black copper and a „low metal bearing“ iron silicate slag are the other products arising. The granulated slag is sold together with the iron silica sand of the KRS submerged lance furnace.

The black copper is tapped into a laddle and either transferred to the TBRC direct or cast in block form.

The crude lead/tin alloy is initially pretreated in an enclosure and then transferred to the refining plant and refined in a further multi-stage process.

The final lead/tin alloy is then cast into 20 – 25 kg ingots in a small casting plant which are then stacked on pallets and taken to the block metal storage hall.

The annual production of lead-tin alloy is about 4,500 tonnes.

### 2.3.2 Anode furnace operation

Impurities are removed from the KRS copper and various copper refining scraps by selective oxidation in the anode furnace. The anode furnace process consists of the following steps:

- charging and melting
- oxidising and slag removal

- reducing (poling)
- casting

The charging operation is performed by a charging crane through the charging openings. Molten converted copper is poured via a launder into the furnace (from the TBRC converting step).

After melting, the feed is refined (oxidised) with the help of air and oxygen that is blown into the bath with tuyeres. The generated refining slag is removed and remelted in the KRS.

Subsequently, the copper in the furnace, which now contains about 1 % oxygen (dissolved as $Cu_2O$), is deoxidised (i.e. reduced or poled). At the main furnace 5 natural gas is used which is blown into the bath via tuyeres. After poling, the copper is ready for casting into anode moulds.

The anode furnaces are heated with oil whereby the flame covers the entire surface of the molten metal. The combustion air is enriched with oxygen.

In addition, the roof of the anode furnace hall is closed. Ventilation is connected to an additional filter plant.

The anode furnace plant has a permit to process up to 300,000 tpa. input materials like copper scrap, KRS copper, spent anodes and fluxes.

### 2.3.3 Tankhouse / electrolyte treatment

The copper refining tankhouse has the task of converting impure anode copper into high-purity electrolytic copper. The impure copper as anode and a stainless steel sheet as cathode are connected in a sulphuric acid electrolyte. With a flow of electricity the anode dissolves. Dissolved copper ions move to the cathode where they are deposited. The anode stays in the cell for 21 days. During this time the cathode is changed three times whereby the deposited copper is washed and stripped in a machine after each changeover. The tankhouse process is performed in a total of 924 cells, each of which accommodates 39 anodes and 38 cathodes.

The anodes are inspected in an automatic machine to ensure the correct weight before being hung in the cells, the anode sheet and the lugs pressed flat and the lower edges of the anode lugs planned to improve the current contact.

After 21 days the original anode has been dissolved except for a small amount of scrap. The leftover scrap is washed, weighed and bundled up in a scrap machine and transported to the anode furnace for recycling.

The cells are cleaned after the anode scrap is removed. The deposited anode slimes that are a high-grade precious metal bearing product are collected and transported to the leaching plant for processing. The treated anode slimes are then processed at the Hamburg site and the precious metals, mainly gold and silver, which are partly, in traces, content of diverse raw materials are extracted in a saleable form.

A stipulated amount of the electrolyte must be constantly removed from the system in order to limit the level of impurities. The electrolyte is treated in the leaching plant where nickel sulphate is produced.

The stripped copper cathodes from the refining tankhouse are inspected by an optical scanning system and visually by the machine operator. Faulty cathodes can be removed from the production line straight away. Good cathodes are sampled, weighed, labelled and bundled up.

During electrolysing of copper anodes a slime settles at bottom of the tank house cells. This slime is called anode slime and enriches the precious metals, mainly gold and silver, which are partly, in traces, content of diverse raw materials.
The anode slime is finally refined in the precious metals facility at our Hamburg plant.

### 3. Organisation

The Supply Chain Management (Recycling Raw Materials Procurement) based in Aurubis Luenen is responsible for the procurement of secondary raw materials for the entire company. The works management is responsible for production control at Luenen site. The Quality Management and Environmental Management officers are directly responsible to the works management.

## 7. Audits

The Quality Management and Environmental Management officers as well as Supply Chain Management (Recycling Raw Materials Procurement) keep the information sent out to the customers updated.

## 8. Updating service

Changes to this document can only be made if agreed with the IMS officer and the works management of Aurubis AG, Luenen.

## 9. Distribution

IT, complete Luenen works

## 10. Documentation:

IT, ECTR

## 11. Accompanying documents:

Company brochures
Current company presentation
Website of Aurubis AG
**www.aurubis.com**, and
**https://www.aurubis.com/recycling**