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STANDARDIZATION NEWS

1921-1950: Metals

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- Metallic and Inorganic Coatings

SN
AUGUST 1998

Copper Standards

WROUGHT BY SEVEN DECADES OF SUCCESSFUL PARTNERSHIP

by Arthur Cohen

Arthur Cohen, consultant to the Copper Development Association Inc. (CDA), recently retired from his position as manager of Standards and Safety Engineering with CDA. The 1996 chairman of the ASTM Board, Cohen has received the ASTM Award of Merit (1977), the Committee B-5 Certificate of Appreciation (1981), the Copper Club/ Committee B-5 Award (1983) and the SES Leo B. Moore Medal (1992), among many other awards. He has authored over 50 articles and several chapters for technical handbooks.

The Partnership

ASTM Committee B-5 salutes the Society's centennial. The committee was formed in 1929 as an outgrowth of Committee B-2 on Nonferrous Metals and Alloys. Its mission was to create copper standards in cooperation with the Copper and Brass Research Association and its successor, the Copper Development Association Inc.

This seven-decade partnership with ASTM has established worldwide-accepted standards that reflect the great advances and technological changes which have occurred within the industry. Canada has also completely embraced ASTM copper standards.

There are many breakthrough areas where ASTM standardized products and test methods have been introduced. They are described in the following sections by processes, products, markets and service areas.

Innovative Processes

Mining and Ore Handling

The early U.S. copper industry, located primarily in the American West (Arizona, Utah, New Mexico, Montana, and Alaska) was restricted to mining very rich copper-containing minerals. The introduction of the flotation process in the late nineteenth century permitted the extraction of copper and other metals (including gold and silver) from low-grade porphyry ores. Figure 1 illustrates the ore haulage from an early mine using small rail cars, whereas today's ore handling employs 200- to 300-ton trucks and

Figure 1 - In 1882, ore cars rumbled down the canyon from the mine propelled by gravity.

gigantic shovels (Figure 2). In the mid-1980s, one mine introduced a gigantic, highly engineered conveyor system (Figure 3).

Flash Smelting

Improved bath and smelting technologies have successfully increased smelter productivity and efficiency, while enabling compliance with increasingly stringent environmental restrictions.

Electrorefining

In the past decade, starting sheets made of stainless steel or titanium have been substituted for the traditional copper in a number of refineries employing the electrolytic refining process. Deposited copper is separated from the stainless steel or titanium starting sheet by use of a guillotine and/or by flexing with an air blast. Very significant labor-cost reductions have also been achieved because of the introduction of automated handling of anodes and cathodes in the tank house.

Solvent Extraction

Traditional sulfide ore grades require conventional milling, smelting, and refining. Solvent extraction permits the processing of low-grade oxide ores at much lower cost (Figure 4).

In the first stage (leaching), acidic water (dilute sulfuric acid) is distributed over 60-foot high ore pile layers by wabblers, drip irrigation devices or sprinklers (rain birds), and allowed to percolate through the pile dissolving copper as it penetrates (Figure 5). The copper-laden water or "pregnant leach solution" exits from the bottom of the ore pile or dump and flows to a collection pond from which it is pumped to the solvent extraction plant. The pregnant leach solution is then mixed vigorously with a kerosene-based solvent containing an organic chemical specifically designed to extract copper. The copper-laden organic material, loaded organic, is next mixed with a copper-bearing sulfuric acid solution known as the electrolyte or the aqueous solution. In the mixing and settling stage, the copper is transferred from the organic to the aqueous solution, filtered and then pumped to the electrowinning tank house.

Electrowinning

In the electrowinning stage, copper from the rich electrolyte is deposited for seven days onto either copper cathode starting sheets or stainless steel or titanium mother blanks as in the electrorefining pro-

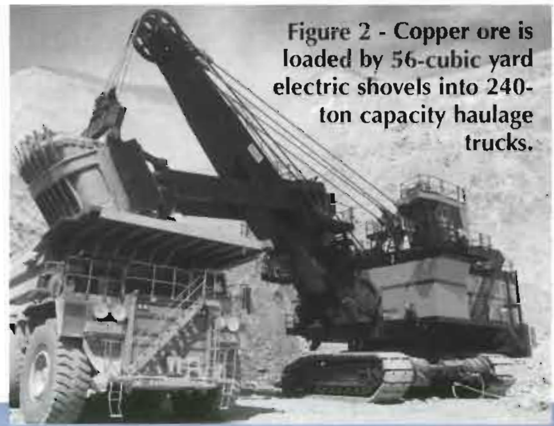


Figure 2 - Copper ore is loaded by 56-cubic yard electric shovels into 240-ton capacity haulage trucks.

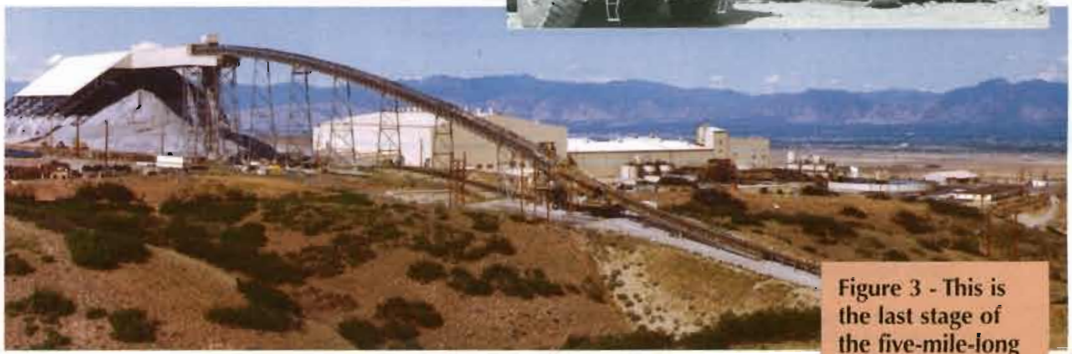


Figure 3 - This is the last stage of the five-mile-long conveyor system that delivers, daily, 130,000 tons of copper ore to the stockpile.

Figures 1, 2 & 3 courtesy of Kennecott Utah Copper Corporation

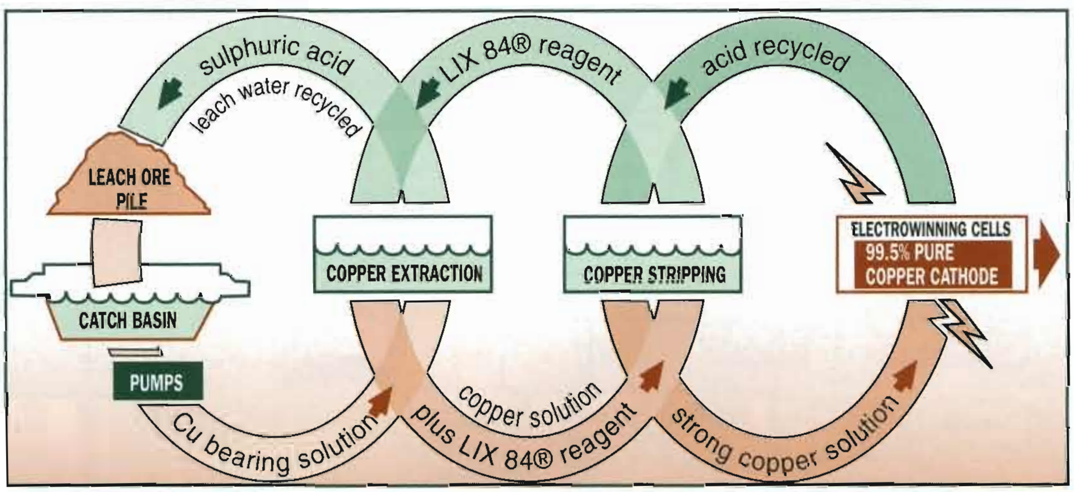


Figure 4 - Stages Involved in the Solvent Extraction and Electrowinning of Copper from the Low-Grade Oxide Ores.

Courtesy of BHP Copper Metals

Figure 5 - Leaching of Copper by Percolation of Dilute Sulfuric Acid through the Ore Pile.

Courtesy of Phelps Dodge Tyrone Inc.

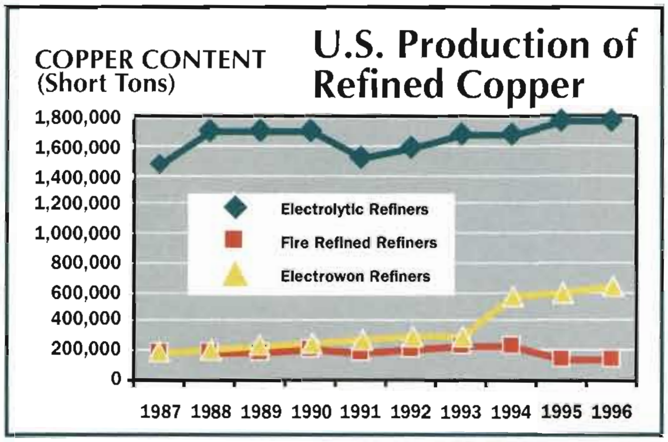


Figure 6 - Annual U.S. Refined Copper Produced by Electrolytic Refining, Fire Refining, and Electrowinning from Solution

Courtesy of the American Bureau of Metal Statistics

Figure 7 - Recycled Copper Metal Scrap

Courtesy of Cerro Copper Products Co.

cess. The anode is made of lead. In 10 days, each copper starter sheet grows from its original weight of about 17 lbs (7.7 kg) to a cathode of virtually pure copper weighing about 200 lbs (90.8 kg). The electrowon copper cathode produced meets the requirements of ASTM B 115, Specification for Electrolytic Cathode Copper, which, along with electrorefined copper, is traded on the world's metal exchanges. Figure 6 compares the annual production by the three commercial processes over the past 10 years—electrolytic refining, fire refining and electrowinning from solution.

Flow of Copper

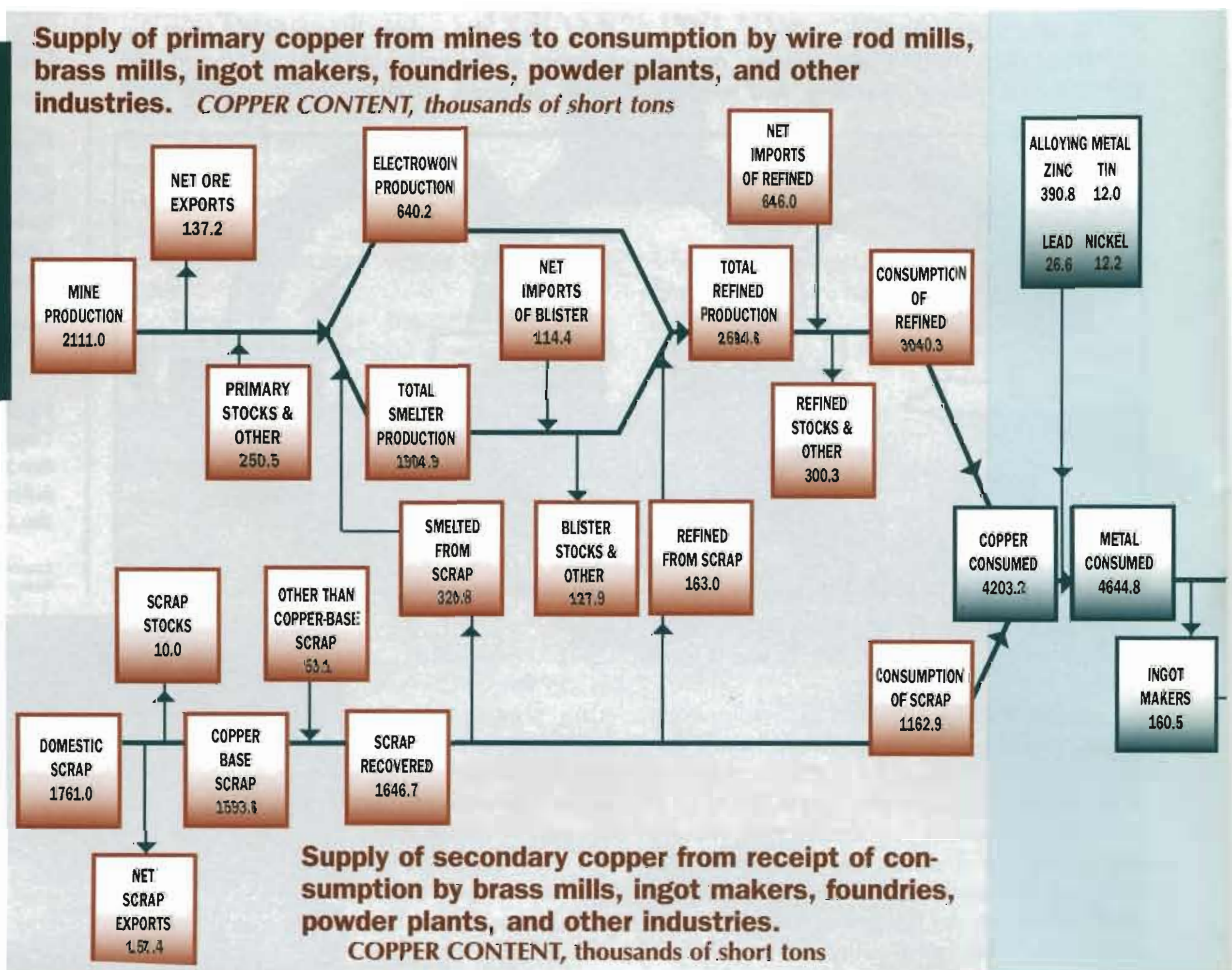
The flow of copper from mine or recycled metal scrap pile (Figure 7) to end markets is illustrated in Figure 8. In brass mill operations, alloying metals such as zinc, lead, tin and nickel are introduced which are covered by companion ASTM specifications under the jurisdiction of Committee B-2.

Continuous Casting

Probably the single most important innovation in the copper industry in the past generation, from a commercial and technological standpoint, has been the introduction of continuous wire rod technology. Rod produced by this method is the basic feed material for

Figure 8 - COPPER SUPPLY AND CONSUMPTION IN THE UNITED STATES, 1997

COURTESY OF THE COPPER DEVELOPMENT ASSOCIATION INC.



the electrical wire and cable industries.

Changes in production techniques came very fast, leading to almost worldwide replacement of the traditional 250-lb (113.5-kg) wire bar with the continuous wire rod product. Figure 9 compares the size of a coil produced from a single 250-lb wire bar to the 10,000-lb (4,540-kg) coil produced by continuous casting. Coil size is limited only by the capacity of the handling equipment. Figure 10 (next page) illustrates copper receipts by wire rod mills as cathode, which is essentially equal to that portion continuously cast. Continuously cast wire rod meets the requirements of ASTM B 49, Specification for Hot Rolled Copper Redraw Rod for Electrical Purposes.

Continuous or semi-continuous casting is also used to produce cast cake for conversion into plate, sheet, and strip, as well as for continuously cast logs which are sawn into billets and are the intermediate products for conversion into pipe, tube, and rod.

Innovative Products

Increasing numbers of fabricating companies have converted their multi-alloy multi-product lines into single product lines with a limited number of alloys. Examples include tube, strip, and rod products, the manufacture of which was encouraged by processing improvements.

Analytical Control

Refineries and brass mills have benefited from the introduction of analytical instrumentation that permits very rapid determination of the chemical composition of the molten metal in the holding furnace and provides impurity control prior to casting.

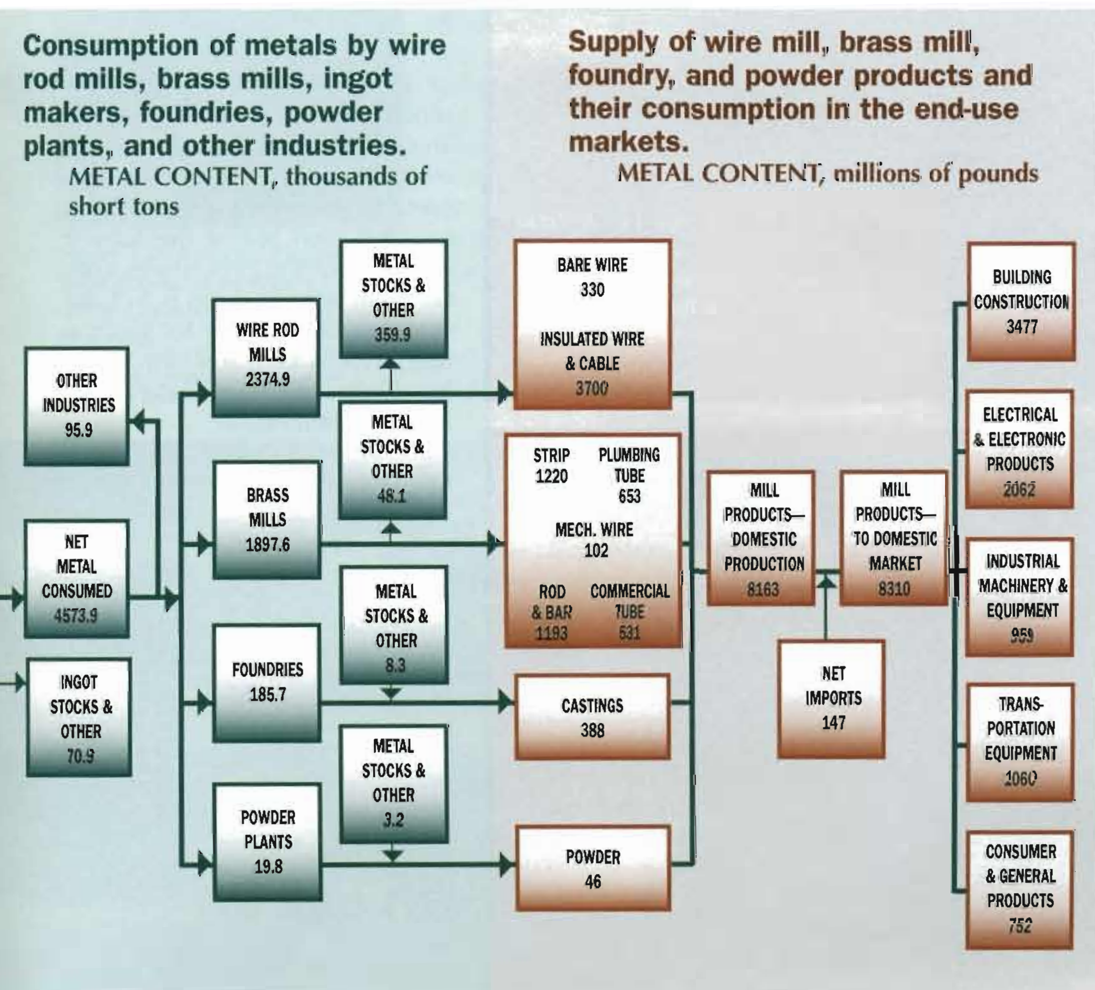
Seamless Tube

Advances in the manufacture of seamless copper tube for plumbing, refrigeration, medical gas, natural gas and liquefied petroleum gas have helped make copper the overwhelming material of choice in quality residential, commercial, and industrial building construction.

Historically, seamless copper tube production began by converting a solid billet to a hollow shell by a piercing process. Extruded shells of much thinner wall thickness were introduced to the market in the

Figure 9 - A 10,000 lb. (4535 kg) copper coil produced by continuous casting dwarfs a coil produced from a single 250 lb. (113 kg) wire bar.

Photo from the Author's Collection



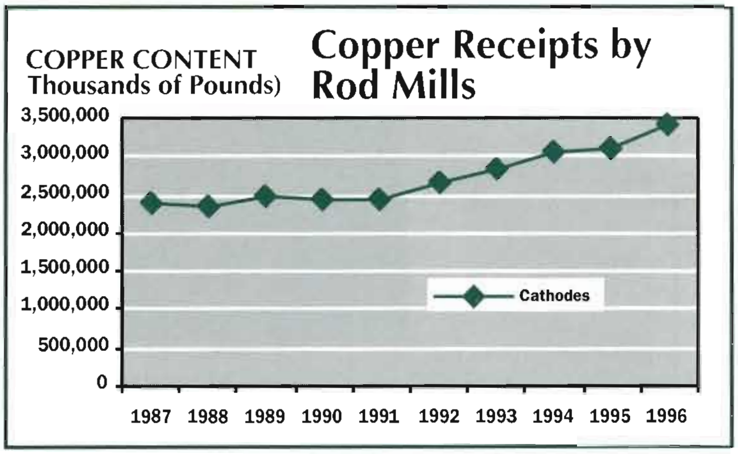


Figure 10 - Copper Receipts by Wire Rod Mills as Cathode

Courtesy of the American Bureau of Metal Statistics

1950s when large extrusion presses became available that could provide the necessary higher extrusion ratio (Figure 11). Further, these shells were suitable for cold drawing on bull blocks and spinner blocks in significantly higher unit weights than was formerly possible on draw benches.

A major development in bull block design was the extensive use of spinner or continuous blocks for tube drawing, a principle adopted from the wire industry (Figure 12). High-speed combination machines clean, straighten, test, mark and cut the tube to specified lengths before discharging the product to bundling equipment for straight lengths or recoiling it for subsequent bright annealing of the stock for users of soft coils.

The irregular wall thickness tolerances that existed in ASTM B 88, Specification for Seamless Copper Water Tube, were converted to a uniform ±10% several years ago. They are currently being restudied based on an in-depth engineering evaluation.

Seamless tube intended for air-conditioning applications is being increasingly made by the Schumag process, which involves a straight draw with a carbide floating plug. This process provides improved wall thickness control with superior concentricity.

Tube for medical and natural or LP gas applications requires superior inside surface cleanness. This requirement is accommodated by immersing the tube in tanks containing suitable chemical cleaners, and then testing the tubular product per the procedures contained in Specifications B 819, for Seamless Copper Tube for Medical Gas Systems or B 837, for Seamless Copper Tube for Natural Gas and Liquefied Petroleum (LP) Gas Fuel Distribution Systems.

Welded Tube

In the mid-1960s, welded copper and copper alloy tube produced from strip without the use of a filler metal became commercial (Figure 13). Strip from payout reels is formed in successive stages to the round tubular shape, and is then welded by one of several optional methods. The domi-

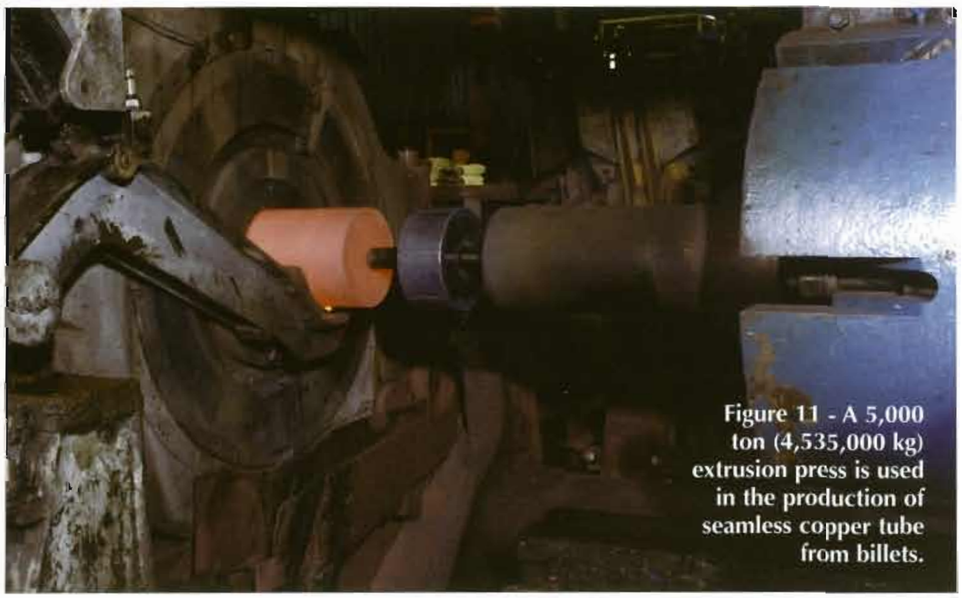


Figure 11 - A 5,000 ton (4,535,000 kg) extrusion press is used in the production of seamless copper tube from billets.

Figure 12 - A tube shell emerges from a press after the preliminary extrusion cycle.

Figures 11 & 12 Courtesy of Cerro Copper Products Co.

nant specifications are ASTM B 447, Welded Copper Tube and ASTM B 543, Welded Copper and Copper Alloy Heat Exchanger Tube. Major advantages include the opportunity to use excess brass mill strip capacity, the production of selected tube lengths without metal wastage, the production of long level wound coils suitable for use in refrigeration and air conditioning, and other uses as oil and gasoline lines. Tighter wall thickness tolerances are another advantage.

In household application, the use of welded yellow brass (C26000) tube shows slow but steady growth in plumbing, drainage (sink traps) and architectural applications as well as products such as (head/footboards and lamp poles).

Enhanced Tube Surfaces

The revised specification ASTM B 359, Specification for Copper and Copper Alloy Seamless Condenser and Heat Exchanger Tubes with Integral Fins, is specified for highly engineered surface condensers, evaporators and other specialized air-conditioning equipment. A companion specification using welded tube blanks is also under development. Such tube has had its external or internal surfaces, or both, modified by a cold forming process to produce an integral enhanced surface for improved heat transfer associated with nucleate boiling (Figure 14). Prompting this effort has been the withdrawal from worldwide production of certain ozone layer destroying refrigerants such as R11 and R12 according to the 1995 Montreal Protocol. The replacement refrigerants R134a and R123, while not exhibiting this destructive behavior, are not as thermodynamically efficient; hence the need for tube with superior heat transfer characteristics.

Figure 13 - Assorted Copper Tube Produced by One of the Optional Welding Processes

Figures 13 Courtesy of Outokumpu American Brass Company

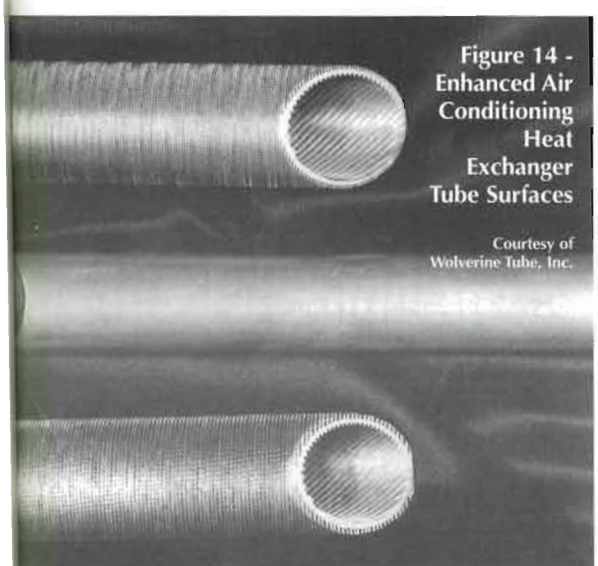


Figure 14 - Enhanced Air Conditioning Heat Exchanger Tube Surfaces

Courtesy of Wolverine Tube, Inc.

Figure 15 - Precision Slitting of Brass Sheet into Strip.

Figure 16 - Strip Annealing Furnace

Figures 15 & 16 Courtesy of Outokumpu American Brass Company

Plate, Sheet and Strip

These products start as direct chill cast cake whose size has increased from 7,000 lbs to 55,000 lbs (3,200 kg to 25,000 kg). Because of the larger coil sizes being produced, improved metal quality and production efficiencies are achieved. Precision slitting for strip width control and freedom from edge burrs along with other improvements are now standard (Figure 15). A strip annealing furnace (Figure 16), which provides superior grain size control, reduces labor requirements, and conserves factory floor space over conventional bell annealing furnaces, has been introduced into production operations.

Bus Bar

Rolling has largely replaced drawing procedures in domestic fabricating mills leading to improved product quality and production efficiency.

Not well known is a contribution made by the U.S. copper industry to the Manhattan Project during World War II. There was an

Figure 21 - Canadian Metal Dollar/Two-Dollar Coins

Photo by Art Cohen

monly referred to as "Loonies" (so named for the symbol of the loon on the back of the one-dollar coin) and "Toonies" (Figure 21).

In February 1998, the U.S. Coin Coalition met with representatives of the U.S. Department of the Treasury and the U.S. Mint to review technical aspects of a new dollar coin. The coin, expected to be a copper alloy, is scheduled for minting in the year 2000 as part of Public Law 105-124 (December 1, 1997).

The law specifies that the new coin shall have the same diameter as the current Susan B. Anthony coin, that it be golden in color with a discernable edge, and that the coin and its components (strip and blanks) be manufactured within the United States. Design and security requirements, which refer to a unique electromagnetic signature for measurement by automatic coin reading machines, are also critical. The U.S. Mint is seriously testing two clad metal systems—a Golden Nordic coin (similar to the Swedish kronor) and a modified British pound. Public and commercial acceptance of the new dollar coin will dictate whether the dollar note will be withdrawn.

Copper Roofing

For the past decade and more, there has been steady growth in copper sheet and strip for copper roofing in the United States and Canada. Figure 22 shows the newly installed roof on the Canadian Parliament Building in Ottawa, Ontario. Specification ASTM B 370, Copper Sheet and Strip for Building Construction, in its multiple thicknesses or gages, is the basis for specification and purchase. Fueling this healthy market are the competitive availability of the metal plus the confidence in copper.

Just recently adopted has been ASTM B 882, Specification for Prepatinated Copper for Architectural Applications. Such a product has long been wanted by architects and engineers who did not want to wait years for the copper roof or building fascia to develop the prized green color.

Low-Lead and Lead-Free Wrought and Cast Copper Alloys

Concern about the health effects of lead leached into water prompted the reconsideration of existing alloys and the development of new alloys for potable water application. Pressure tightness for castings and superior machinability for both wrought and cast

Figure 22 - New copper roof is installed on the Canadian Parliament Building, Ottawa, Ontario, Canada.

Courtesy Canadian Copper & Brass Development Association

components provided by the lead addition were mandatory requirements. Wrought and cast lead-free bismuth containing alloys met these properties including the health requirements of ANSI/NSF 61, Drinking Water System Components—Health Effects. An acidified sodium acetate wash has been demonstrated to remove smeared lead following machining.

Concern has been expressed by some segments of the industry for mixed scrap in which trace amounts of bismuth could lead to hot shortness of the metal during processing. Procedures for rigid control and segregation of recycled scrap are under study by the Institute of Scrap Recycling Industries (ISRI) and the Brass and Bronze Ingot Manufacturers (BBIM).

Household Products

In household products, copper metals are selected because of their superior combination of appearance, quality, image, design factors, physical and mechanical properties, and long service life. Electrical lighting fixtures is the major household product category along with fireplace equipment.

Service Activities

Susceptibility of Copper Materials to Stress Corrosion Cracking

The traditional method for determining a copper material's sensitivity to stress corrosion cracking has always been the mercurous nitrate test (ASTM B 154). In response to the request from the ASME Boiler and Pressure Vessel Code and the U.S. Coast Guard, Committee B-5 undertook the conversion of ISO 6957, Copper Alloys—Ammonia Test for Stress Corrosion Resistance, to ASTM format. This was prompted by their concern for test solution and specimen disposal. ASTM B 858M, Test Method for Determination of Susceptibility to Stress Corrosion Cracking in Copper Alloys Using an Ammonia Vapor, is now official. The test method simulates service conditions under which stress corrosion cracking may occur and overcomes the shortcomings of the mercurous nitrate test.

The Future

The world's economy is rapidly becoming global. With the approach of the 21st century, third world countries are establishing telecommunications links, becoming greater consumers of electricity, and they are constructing homes, factories, and commercial buildings. Copper will be required to meet these needs. Copper has been used as an engineering material for almost 10,000 years, and its services to mankind are myriad. It is impossible to envision a world without it. **SN**

The Metal of Civilization

Standards B 115 and B 49

Copper is one of the most pervasive metals in our society. About 16.7 million metric tons of copper is produced in the world annually, of which about 20 percent is produced in the United States.

Used in just about any electrical motor, from your refrigerator to your washing machine, as well as plumbing and sanitary systems throughout the world, copper has contributed more to the well-being of the human race than nearly any other metal, says Paul Tandler, chairman of subcommittee B05.07 on Refined Copper, part of Committee B-5 on Copper and Copper Alloys. Although he admits he may be biased, he considers copper "The Metal of Civilization."

Accordingly, we might consider standard B 115, Standard Specification for Electrolytic Cathode Copper, "The Specification of Civilization." B 115 is accepted worldwide as the ultimate standard for the production and commercial trading of copper, says Tandler. The document establishes the requirements for electrolytic copper cathode—electrorefined and electrowon. Electrolytic copper cathode is produced throughout the world and is the base material for the numerous rolled, drawn, extruded, cast, and forged products made from copper and its alloys. "This pure form of the metal is required in the production of products for the electrical, electronic, communications, plumbing, and construction industries, among others," he says.

A table included in B 115 indicates the required chemical composition of these high-purity cathodes. The table shows the allowable levels of impurities for both Grade 1 and Grade 2 cathodes, including limits to selenium, tellurium, bismuth, antimony, lead, arsenic, iron, nickel, tin, and more in trace quantities. In addition to chemical composition requirements, B 115 also includes physical property requirements, as well as two annexes providing sampling and specimen preparation information and test methods for determining compliance with chemical composition requirements.

The most common uses of cathode are for the production of rod and wire. More than half of all the copper in the world is used to make electrical conductor grade wire, explains Horace Pops, chairman of Committee B-5. And it is the most recycled of all metals; only 12 percent of the 5.8 trillion pounds of known copper ore has been mined throughout history. In fact, nearly all of the mined copper is still in use today.

Important to note, says Pops, is the fact that B 115 has stood the test of time and since it was first published, in 1938, has been continually revised to address new technology. "After 60 years, the standard is as important as it ever was, and it will be for years to come," he says.

Older cousin to B 115 is B 49, Standard Specification for Copper Redraw Rod for Electrical Purposes, which was first developed in 1923. The introduction of continuous wire rod technology in the '70s was an important innovation in the copper industry (see feature article by Arthur Cohen, p. 34). These changes in production techniques prompted numerous changes to B 49. The document covers copper redraw rod in diameters from 1/4 to 1 3/8 in. (6.4 to 35 mm) which is suitable for further fabrication into electrical conductors. Like B 115, the document also covers chemical composition, and mechanical properties and includes test methods addressing chemical analysis, tensile elongation, electrical resistivity, embrittlement, and more. In recent years, B 49 has been expanded to include requirements and test methods for the thin oxide film that is present on the surface of rod and wire. If excessive, manufacturing problems might occur downstream, affecting drawability, solderability, and the adhesion of surface coatings.

In the form of cathodes, bars, coils, rods, or any other shape, copper is one of the most versatile, malleable, and workable metals, says Tandler. "We are blessed on this earth to have it," he says. And we are equally blessed by Committee B-5's work on standards B 115 and B 49 to make it pure, functional, and readily available.

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