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## ECO BRASS

ECO BRASS was developed as a Pb-free copper alloy and total sales have exceeded 110,000 tonnes. ECO BRASS is mainly used for water meters, valves and other components in water supply sector, but it is also selected by the automobile industry. ECO BRASS has been used for components in more than 16 million cars. ECO BRASS is not only Pb-free but also a high performance copper alloy which is superior in strength equivalent to stainless steel, machinability, and corrosion resistance. These properties satisfy economic efficiencies of society by reducing weight and thickness of components, while reducing its environmental burden.

### I. Market Trend

#### 1. Status of License

- Fig.1 is a mapping of the ECO BRASS licensees.
- Since 2003, we made license agreements with 26 companies in total, including 9 rod and casting companies in Europe and 5 rod and casting companies in North America.
- We established an ECO BRASS supply chain providing material comprised of the same composition and quality in all the major producing countries around the globe.



Fig.1 ECO BRASS Licensee Mapping

## 2. Trends in Sales of ECO BRASS

- Fig. 2 shows the steady growth of global sales and Fig. 3 shows the area breakdown of the first half of 2014 sales.
- Sales have increased steadily since 2007 as regulation of lead (Pb) has tightened. Total global sales to June 2014 amounted to 112,000 tonnes.
- First half (January - June) 2014 global sales totaled 16,125 tonnes with a monthly average of 2,688 tonnes.
- First half 2014 sales increased 3.5 times compared to 2009 when the previous evaluation of the ELV lead (Pb) exemption was carried out.
- Regional ratios: ASIA: 19% Europe: 37%, North America: 44%.
- Fig. 4 shows 2014 first half global sales breakdown of rod and Fig. 5 shows sales of rod by region.
- In 2014 first half (January - June), global sales came to 12,528 tonnes and monthly average is 2,088 tonnes.
- The monthly average (2,088t/m) equals 3% of the production of copper alloy rod containing lead (Pb) in Japan, North America, and Europe.
- Regional ratio ASIA: 10%, Europe: 46%, North America: 44%
- European rod sales have markedly increased with 2014 first half sales (968t/m) 3 times greater than sales in 2012 (317 t/m) and exceeds sales in North America (908t/m).

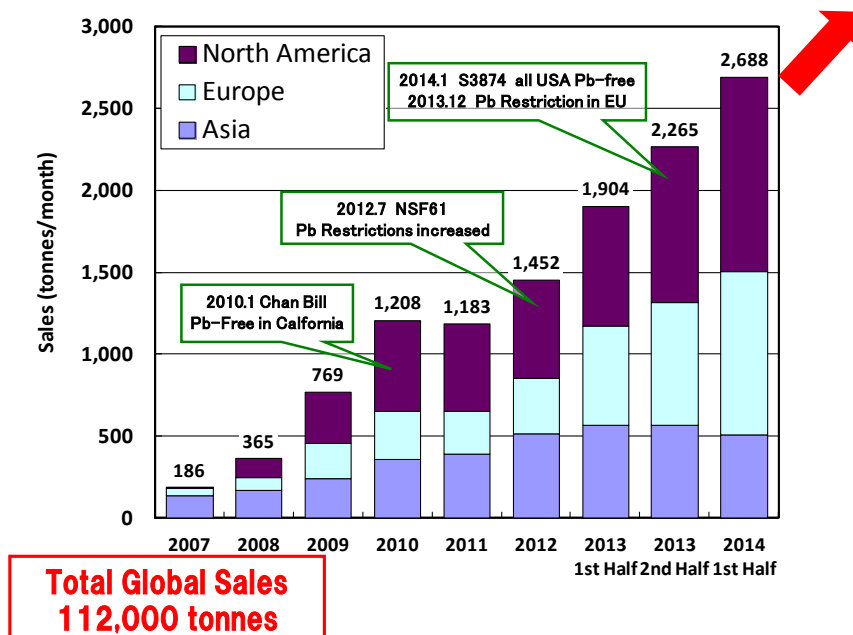


Fig.2 Growth of Sales

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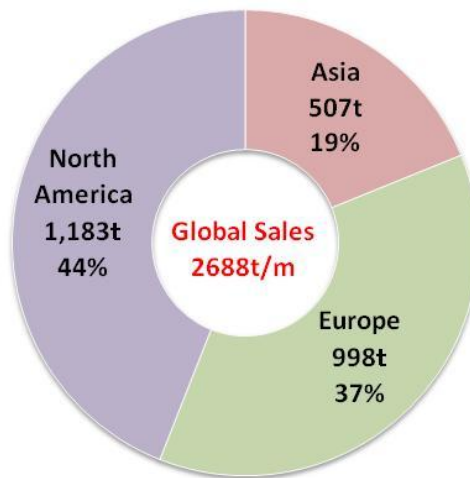


Fig.3 Area Breakdown First Half 2014 Global Sales



Fig.4 2014 First Half Global Sales Breakdown of Rod

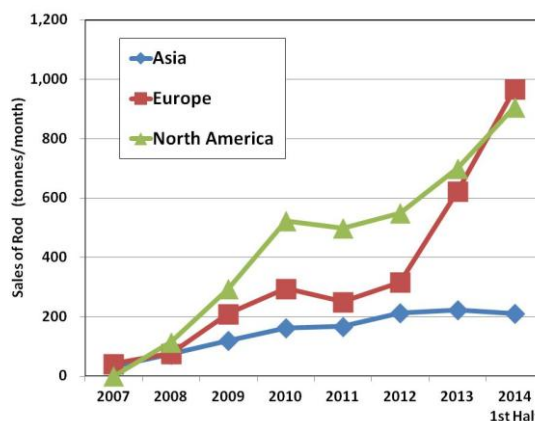


Fig.5 Sales of Rod by Region

### 3. Example of sales in Japan for ECO BRASS

- The most common use of rod in the automotive sector is the control valve for variable displacement air-conditioner compressors.
- This valve was originally made from leaded brass C36000 (equivalent to JIS H 3250 C3604), however, due to wear resistance and cavitation erosion there were many part failures resulting in defective air conditioners.
- ECO BRASS is superior in cavitation erosion and wear resistance, thus, about 40% of the market switched to ECO BRASS. We presume that market share will increase in the future.
- Fig.6 shows changes in sales of control valves for variable displacement air-conditioner compressor.

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- ECO BRASS was selected in 2007, and current monthly sales are about 100 tonnes. We estimate the number of automobiles using ECO BRASS parts might have come to 16 million calculated from weight of material sold.

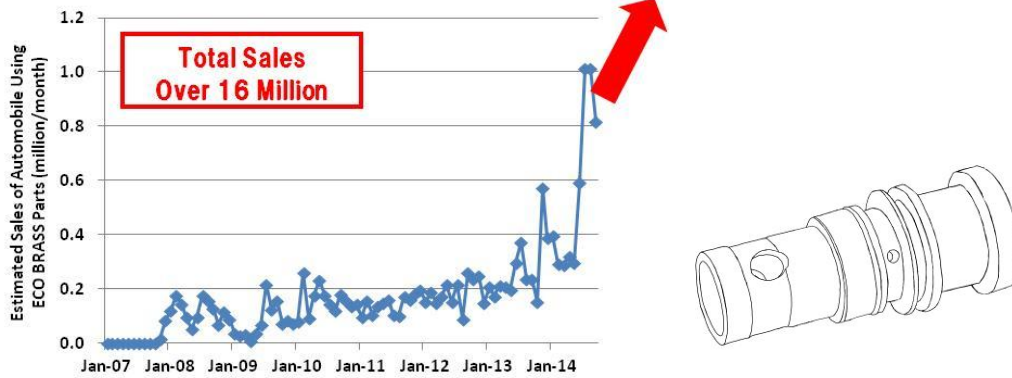


Fig.6 Sales of Control Valve for Variable Displacement Air-conditioner Compressor and Drawing

- Fig.7 shows some applications for automobile parts and Fig.8 shows some applications for others.

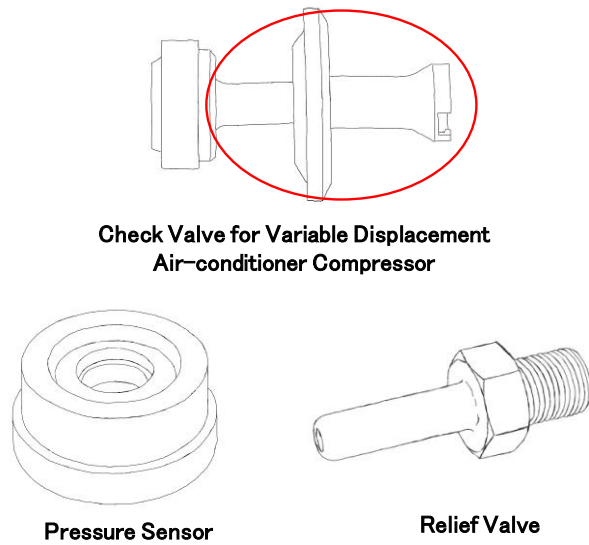


Fig.7 Example of Automobile Parts Selected for High Performance

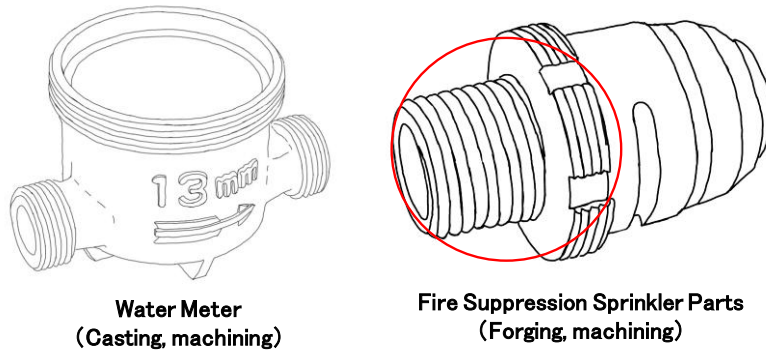


Fig.8 Example of Products Made from ECO BRASS

- Check valve for variable displacement air-conditioner compressors is a very small part weighing just 0.5g. Estimated sales of automobiles using this ECO BRASS part is about 14 million calculated from weight of material sold.
- Corrosion resistance and erosion corrosion resistance are important quality for water meters.
- At the change-over to Pb-free materials, bismuth (Bi) bronze (C89833, 88Cu-5Sn-2Bi-5Zn) was initially selected and it used to have about 80% share of market. However, as the yield and productivity of ECO BRASS is equivalent to C83600 (85Cu-5Sn-5Pb-5Zn), the market switched to ECO BRASS which now accounts for about 85% of the market.
- Water meters are produced by casting and machining. According to casting manufacturers, it is possible to improve the yield rate and productivity of ECO BRASS to the same level as C83600 by optimizing manufacturing conditions.
- Components of fire suppression sprinklers are in constant contact with water and superior corrosion resistance and stress corrosion cracking resistance are important qualities. Sales volume of this part came to 16 million or more and part reliability has been established.
- Fire suppression sprinklers are produced by hot forging and machining. They are easily mass-produced when forging temperature and machining conditions are optimized.

## II. Detailed Properties of ECO BRASS

- Table 1 shows the properties of ECO BRASS compared to C36000 (equivalent JIS H3250 C3604).

Table 1 Properties

Properties		ECO BRASS	C36000	C36000 ratio	
Physical Properties	Specific Gravity	8.30	8.50	0.98	
	Melting Point – Liquidus	°C	885	895	0.99
	Melting Point – Solidus	°C	875	880	0.99
	Specific Heat	J/kg·K	480	450	1.07
	Thermal Conductivity	W/m·K	45	133	0.34
	Electrical Conductivity	%IACS	8	26	0.31
	Coefficient of Thermal Expansion	10 <sup>-6</sup> /K	19.9	20.5	0.97
	Modulus of Longitudinal Elasticity	GPa	98	85	1.15
	Modulus of Transverse Elasticity	GPa	34	35	0.97
Mechanical Properties	Tensile Strength (φ 20)	MPa	670	475	1.41
	0.2% Proof Stress (φ 20)	MPa	510	355	1.44
	Elongation (φ 20)	%	30	20	1.50
	Vickers Hardness (φ 20)	5kg	190	145	1.31
	Poisson's Ratio		0.33	0.32	1.03
	Cold Compressive Stress	MPa	700	515	1.36
	Cold Compressive Proof Stress	MPa	435	290	1.50
	Cold Limit Compressibility	%	29	45	0.64
	Bending Stress	MPa	1230	785	1.57
	Fatigue Limit(10 <sup>7</sup> )	MPa	205	125	1.64
	Creep Strength, Stress at 0.5% Creep Strain(MPa)	100h at 90°C	–	about 330	–
100h at 120°C		≤570	about 260	–	
100h at 150°C		about 490	about 200	–	

- ECO BRASS rod has 1.4 times higher tensile strength than leaded alloy C36000. Because of this the thickness and weight of components can be reduced.
- The elongation of ECO BRASS rod is equal to or better than leaded brass C36000.
- Cold compression strength, bending stress, and fatigue limit of ECO BRASS are 1.4 - 1.6 times greater than those for leaded brass C36000.
- Electrical conductivity and thermal conductivity of ECO BRASS is equal to 1/3 of those for leaded brass C36000.
- Creep strength of ECO BRASS at 120°C/150°C is equal to 2 times of that for C36000 or greater.
- Table 2 shows various properties.

Table 2 Properties

Ref.	Properties	ECO BRASS	C36000	C36000 ratio	
1)	Tool Life(Frank Wear-Turning)	pieces	4400	6300	0.70
1)	Tool Life(Frank Wear-Drilling)	pieces	4200	5900	0.71
2)	Wear Loss(No Lubrication)	mg	5.0	91.5	0.05
2)	Wear Loss(Lubrication)	g	0.3	13.3	0.02
3)	Cavitation Erosion Loss	mg	1.7	20.2	0.08
3)	Mean Erosion Rate	μ m/h	2.8	30.5	0.09
4)	Max Corrosion Depth(ISO6509)	μ m	5	1000	0.01
4)	Max Corrosion Depth(JBMA T-303)	μ m	5	160	0.03
4)	Stress Corrosion Cracking Sensitivity		0.005	1.0	0.01

1) K. Oishi, "Development of Lead Free Copper Alloy "ECOBASS"<sup>®</sup>", Proceedings of the sixth International Copper-Cobre Conference, August 25-30, Toronto, Ontario, Canada, vol. 1, 2007, 325-340.

2) M. Takasaki, "Wear Characteristics of Free Cutting Copper Alloys", J.JRICu, 53, 2013, 88-94.

3) S. Tanaka, "Cavitation-Erosion Resistance of C6932", J.JRICu, 53, 2013, 139-144.

4) K. Oishi, "Development of Human and Environment-Friendly Copper Alloy "ECOBASS " for Machining, Forging, and Casting", J.JCBRA, 39, 2000, 8-14.

- Cutting force of ECO BRASS is equal to 0.7 times of that for C36000 under conditions when using High Speed Steel (JIS SKH51) without lubricant.
- Productivity of ECO BRASS is equal to that of C36000 by optimizing cutting conditions.
- ECO BRASS is a copper alloy which is superior in wear resistance, cavitation erosion resistance, machinability, dezincification corrosion resistance, and stress corrosion cracking resistance.

### III. Final Comments/Summary

- We made license agreements with leading companies in Asia, Europe, and North America to enable global procurement of ECO BRASS.
- Total sales have exceeded 110,000 tonnes and it has been used as Pb-free material successfully.
- Since October 2014, the monthly sales of ECO BRASS is about 3,000 tonnes and equals 3% of total production of leaded copper alloy rod in Japan, North America, and Europe.
- ECO BRASS is used in automobile components in more than 16 million cars (estimated sales).
- We received many reports that productivity of ECO BRASS is equivalent to leaded brass C36000 (equivalent JIS H3250 C3604), forging brass C37700 (60Cu-38Zn-2Pb), and C83600 (85Cu-5Sn-5Pb-5Zn) by optimizing cutting conditions, forging conditions and other production parameters.
- ECO BRASS is not only Pb-free but also a high performance copper alloy which is superior in strength equivalent to stainless steel, elongation, fatigue strength, creep strength, machinability, corrosion resistance, stress corrosion cracking resistance, erosion corrosion resistance, cavitation resistance, castability, wear resistance, and hot forgeability.

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**ECO BRASS<sup>®</sup>**

- ECO BRASS is an ideal material in order to realize Pb-free industrial society, it has excellent properties in strength equivalent to stainless steel, machinability and wear resistance, which enables producers to reduce the weight and thickness of components leading to economic efficiencies.