OHMALOY® 30 and OHMALOY® 40

Resistance Alloys

(UNS K91470 and K91670)

INTRODUCTION

Ohmaloy® 30 and Ohmaloy® 40 alloys are moderately magnetic, ductile stainless steels having extremely high electrical resistivity. In addition to imparting high electrical resistivity, the aluminum content in these iron-13% chromium-aluminum resistance alloys also provides oxidation resistance. These alloys are capable of resisting oxidation for continuous duty at temperatures up to 1800°F (982°C), and are satisfactory for intermittent heating in temperatures from 1800°F (982°C) to 1900°F (1038°C). These Ohmaloy resistance alloy are classified as UNS K91470 and K91670. These are covered in ASTM B603 as Types IV and III, respectively.

Ohmaloy® 30 and Ohmaloy® 40 alloys are used in many applications requiring dissipation of electrical energy. Some examples are grid resistors for mine locomotives, crane starters and, the largest application, braking resistors for railroad diesel locomotives. These alloys are used where the application demands heavy-duty resistors with a small surface-to-volume ratio. They can also be used in applications where resistance heating is required.

COMPOSITION

Typical Chemical Composition in Weight Percent		
Element	Ohmaloy® 30	Ohmaloy® 40
Carbon	0.025	0.025
Manganese	0.35	0.35
Silicon	0.30	0.30
Chromium	13.00	13.00
Aluminum	3.00	3.95
Titanium	0.30	0.30
Iron	Balance	Balance

METALLURGICAL STRUCTURES

Ohmaloy® 30 and Ohmaloy® 40 alloys are fully ferritic up to their melting temperature, and contain angular titanium carbonitrides randomly distributed throughout their structures. The formation of these titanium carbonitrides randomly distributed throughout their structures. The formation of these titanium carbonitrides is essential for weldability without sensitization, an important factor in achieving highly reliable joints in electrical equipment.

PHYSICAL PROPERTIES

Density

	lb/in^3	g/cm^3
Ohmaloy® 30	0.270	7.48
Ohmaloy® 40	0.267	7.41

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Mean Coefficient of Thermal Expansion*

Temperature Range		Ohmaloy® 30		Ohmaloy® 40	
°F	°C	in/in•°F	cm/cm•°C	in/in•°F	cm/cm•°C
68-212	20-100	$6.4x10^{-6}$	$11.5x10^{-6}$	$6.3x10^{-6}$	$11.3x10^{-6}$
68-932	20-500	$7.1x10^{-6}$	$12.8x10^{-6}$	$6.8x10^{-6}$	$12.2x10^{-6}$
68-1832	20-1000	$8.0x10^{-6}$	$14.4x10^{-6}$	$7.9x10^{-6}$	$14.2x10^{-6}$

Thermal Conductivity

Temperature		Ohmaloy® 30	Ohmaloy® 40
°F	°C	W/cm•K	W/cm•K
122	50	0.158	0.145
212	100	0.165	0.156
392	200	0.181	0.168
572	300	0.194	0.185
734	390	0.209	0.197
896	480	0.221	0.215
1067	575	0.234	0.232
1202	650	0.251	0.245

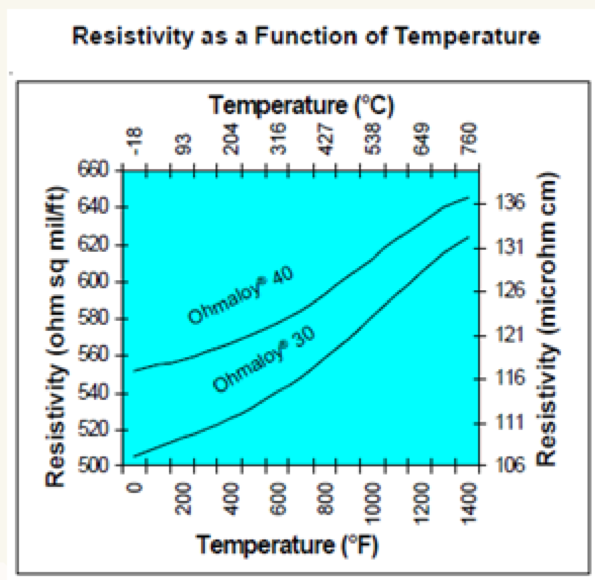
Electrical Resistivity

68°F (20°C)	Ohmaloy® 30	Ohmaloy® 40
microhm-cm	107	116
ohm sq-mil/ft	505	550

RESISTIVITY

Due to the difference in aluminum content, the electrical resistivity of Ohmaloy® 30 alloy is lower than Ohmaloy® 40 alloy. This difference permits the design engineer to select the optimum characteristics for the application. Ohmaloy® 30 alloy parts can achieve, with lighter cross-sectional areas, the same linear resistance of similar parts fabricated from the Ohmaloy® 40 alloy. Some applications, however, require larger mass to assist in the dissipation of heat or in preventing thermal deformations during heating and cooling cycles. In these instances, the higher aluminum Ohmaloy® 40 alloy is used.

Nominally, the room temperature specific resistivity of Ohmaloy® 30 alloy is 107 microhm-cm (505 ohm sq-mil/ft). Ohmaloy® 40 alloy has a nominal room temperature specific resistivity of 116 microhm-cm (550 ohm sq-mil/ft). The change in resistivity of Ohmaloy® 30 and 40 steels with increasing temperature is characterized in the following graph. By comparison, other ferritic stainless steels such as AL 400 HP™ have resistivities in the 60 microhm-cm range.



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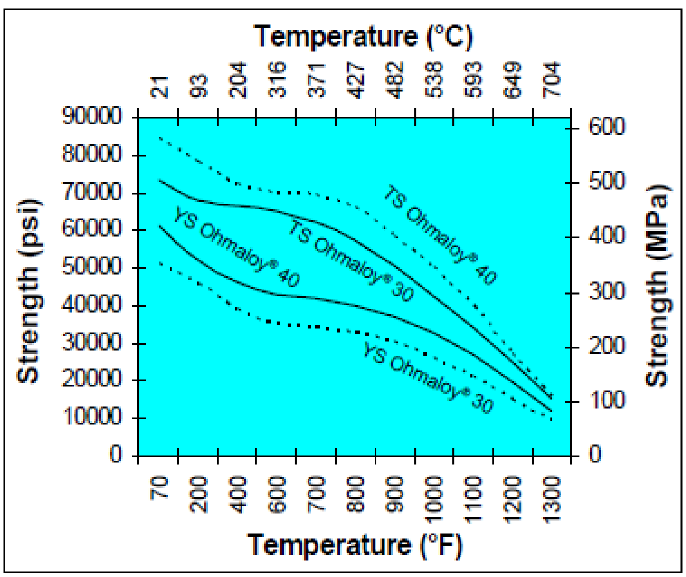
MECHANICAL PROPERTIES

The yield and ultimate tensile strengths of Ohmaloy alloys are a function of both the temperature of test as well as the thickness of the product. The range of properties which are shown in the graph represent differences in test sample gage as well as the effect of aluminum content and annealing treatments.

Typical Tensile Properties

Test Temperature	Ohmaloy® 30	Ohmaloy® 40
77°F (25°C)		
Yield [ksi (MPa)]	55 (379)	65 (448)
Tensile [ksi (MPa)]	76 (524)	87 (600)
Elongation in 2" (%)	28	23
Hardness (Rb)	88	88
1300°F (704°C)		
Yield [ksi (MPa)]	13 (90)	11 (76)
Tensile [ksi (MPa)]	17 (117)	15 (103)
Elongation in 2" (%)	50	30

Typical Elevated Temperature Tensile Properties



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General Corrosion

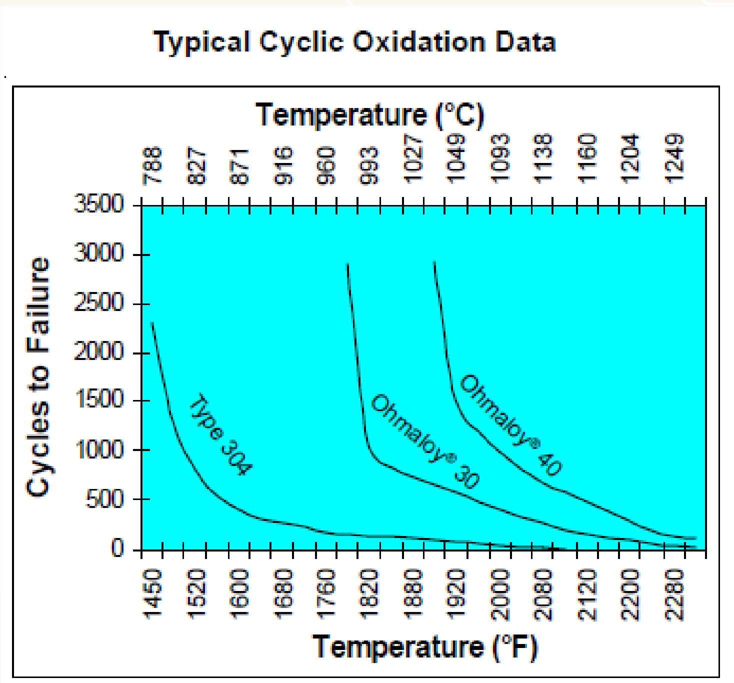
Boiling Solutions	Average Corrosion Rate Inches/year (mm/a)	
	Ohmaloy® 30	Ohmaloy® 40
65% Nitric Acid	0.00864 (2.63)	0.000423 (1.29)
20% Acetic Acid	0.00004 (0.012)	0.00001 (0.003
20% Phosphoric Acid	0.00185 (0.56)	0.00008 (0.024)
10% Sodium Bisulfate	1.8031 (550)	1.7918 (546)
10% Oxalic Acid	0.3992 (122)	0.3577 (109)

HEAT TREATMENT

Ohmaloy® 30 and 40 alloys can be hardened only by cold work. During the fabrication process, it may be necessary to restore the annealed properties after cold work. The alloys are annealed using temperatures from 1600-1650°F (871-899°C) for one hour per inch of thickness followed by air cooling.

CORROSION RESISTANCE

In many corrosive environments, the corrosion resistance of Ohmaloy® 30 and Ohmaloy® 40 alloys is comparable to Type 409 stainless steel. In many cases, they have corrosion resistance comparable to Type 430.



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OXIDATION RESISTANCE

Iron-chromium-aluminum alloys, like Ohmaloy® 30 and Ohmaloy® 40, are the most oxidation resistant iron-based alloys available. They have exceptional oxidation resistance in both continuous and cyclic temperature exposure. The aluminum content provides a tightly adhering alumina protective oxide, and the titanium addition enhances spalling resistance. Coupled with the excellent adhesion of the alumina-oxide, the lower thermal expansion rate of ferritic alloys, as compared to austenitic alloys, further limits spalling during thermal cycling. The higher aluminum content in Ohmaloy® 40 provides a slightly higher cyclic oxidation threshold of 1900°F (1037°C) than Ohmaloy® 30 alloy.

WELDABILITY

Ohmaloy® 30 and 40 alloys have characteristics similar to other ferritic stainless steels and have been welded using standard welding procedures. Being ferritic up to the melting point, they are not hardenable and are not prone to cracking during cooling. Because of the stabilization of carbon as titanium carbonitrides, sensitization is not a concern and post weld annealing is not necessary. When Ohmaloy steel is joined to other stainless alloys, the use of low carbon stainless (Types 304L or 316L), or stabilized grades (Type 321), with low carbon stabilized weld-wire (Type 308) is suggested.

LINEAR RESISTANCE REQUIREMENTS

Generally, Ohmaloy steels are sold based upon a customer's linear resistance requirements. For any given slit-to-width size and gage, the linear resistance (W/ft.) is guaranteed. Two levels of linear resistance tolerance are available, either the standard ±8%, or ±5%. The ±5% tolerance is available at an additional cost, and is achieved by adjustment of the nominal cold-rolled gage to maintain the desirable linear- resistance limits. This flexibility is required because each heat, when melted, deviates slightly from the nominal specific resistivity.

To calculate the required linear resistance from the specific resistivity of the melted alloy, the following basic electrical equations are followed. For a conductor through which a steady state current flows, resistance R is proportional to the length ℓ and inversely proportional to the area of the cross section of the conductor A or:

$$\text{resistance} = R = \rho \, \ell / A$$

where the proportionality ρ (rho) is called the specific resistivity. Therefore, knowing the resistivity of the master heat of Ohmaloy® 30 or 40 steel, the resistance of a given conductor of that material having a uniform cross section can be calculated. Resistivity is an intrinsic material property and is used to calculate linear resistance:

$$\text{linear resistance} – R/\ell$$

$$R/\ell = \rho / A = \rho / (wt)$$

where w is the width and t, the thickness.

To Convert Resistivity Units		
From	**To**	**Multiply by**
microhm-cm	ohm cir-mil/ft	6.0153
microhm-cm	ohm sq-mil/ft	4.7244
ohm cir-mil/ft	microhm-cm	0.7854
ohm sq-mil/ft	ohm cir-mil/ft	1.2732
ohm sq-mil/ft	microhm-cm	0.21167

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