ATOMIC AND CRYSTALLOGRAPHIC

Atomic Number	40
Atomic Weight	91.22
Atomic Volume	10.9 cm^3 / g-atom
Lattice Type	Body Center Cubic

MASS

	METRIC	ENGLISH
Density at 20˚C	6.51 g/cm^3	0.235 lb/in^3

THERMAL

Melting Point	1852˚C	3665˚F
Boiling Point	5425˚C	9800˚F
Specific Heat at 0˚C ñ 100 C	.02847 KJ/Kg-K	(BTU/lb/˚F)
Average Linear Coefficient of Expansion at 0˚C (32˚F)	5.8mm/mm/˚C $\times 10^{-6}$	3.2in/in/˚F $\times 10^{-6}$

THERMAL CONDUCTIVITY

20˚C	.22 Watts/m-K	13BTU ft/hr-ft2˚F

MECHANICAL PROPERTIES OF ZIRCONIUM 702

Tensile Strength (Annealed)	379 Mpa	55,000 PSI
Yield Strength (Annealed)	207 Mpa	30,000 PSI
Modulus of Elasticity (ASTM MIN)		
20˚C (68˚F)	99.2 Gpa	14,400,000 PSI
260˚C (500˚F)	75.2 Gpa	10,900,000 PSI

Zr

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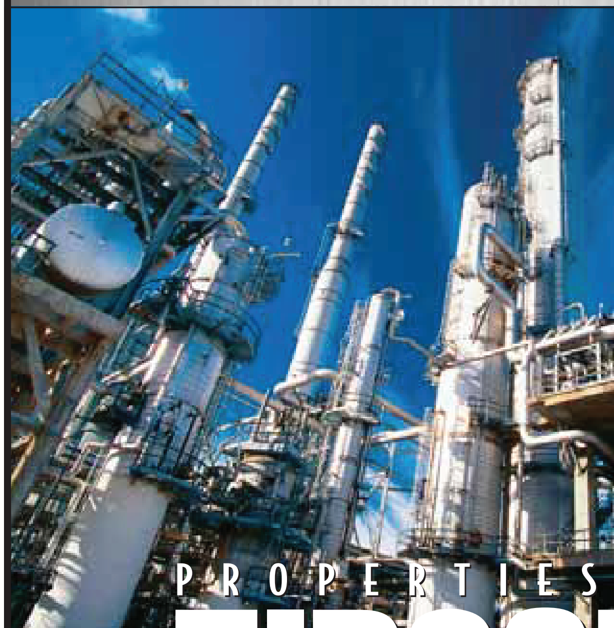

PROPERTIES OF ZIRCONIUM

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APPLICATIONS OF ZIRCONIUM

One of the major applications for zirconium is as a corrosion resistant material of construction in the chemical processing industry. Zirconium exhibits excellent resistance to corrosive attack in most organic and inorganic acids, salt solutions, strong alkalis, and some molten salts. In certain applications, the unique corrosion resistance of zirconium can extend its useful life beyond that of the remainder of the plant. Consequently, maintenance costs are reduced and downtime is minimized. Furthermore, an increasingly important advantage is that zirconium appears to be non-toxic and bio-compatible. Some of the more important areas in the chemical processing industry where zirconium is being used include reboilers, evaporators, tanks, packings, trays, reactor vessels, pumps, valves and piping.

Zirconium is commonly used for corrosion resistance when dealing with the following chemicals:

- Nitric Acid
- Sulfuric Acid
- Acetic Acid
- Formic Acid
- Hydrochloric Acid
- Melamine

NITRIC ACID

Nitric acid is one of the most widely used acids in the Chemical Processing Industry. It is a key raw material in the production of ammonium nitrate for fertilizer, and is also utilized in a variety of manufacturing processes, including the production of industrial explosives, dyes, plastics, synthetic fibers, metal pickling and the recovery of uranium.

Most nitric acid is produced by the oxidation of ammonia with air over platinum catalysts. The resulting nitric acid is further oxidized into nitrogen oxide and then absorbed into water to form HNO3. This process produces acid of up to 70% concentration, with higher concentration acid produced by distilling the dilute acid with a dehydrating agent. Stainless steel has long been used in nitric acid applications; however, it has developed certain serious problems over the years and is subject to several limitations. The superior corrosion resistance of zirconium can overcome some of these limitations, making it an ideal replacement material in many specific nitric acid environments.

Corrosion Resistance of Zirconium in Nitric Acid

		CORROSION RATE (mpy)			
		LIQUID PHASE		VAPOR PHASE	
NITRIC ACID %	IMPURITY	NON WELDED	WELDED	NON WELDED	WELDED
30/50/70	0.1 or 1% $FeCl_3$	<2.5	<2.5	<2.5	<2.5
30/50/70	0.2 or 1% seawater	<2.5	<2.5	<2.5	<2.5
30/50/70	0.1% NaCl	<2.5	<2.5	<2.5	<2.5
30	1% NaCl	<2.5	<2.5	<2.5	<2.5
50	1% NaCl	<2.5	<2.5	12.7	35.6
70	1% NaCl	<2.5	<2.5	<2.5	<2.5
0	Saturated Cl_2	<2.5	102	<2.5	91.4
30	Saturated Cl_2	<2.5	<2.5	<2.5	<2.5
50	Saturated Cl_2	<2.5	<2.5	<2.5	<2.5
70	Saturated Cl_2	<2.5	<2.5	<2.5	<2.5
30/50/70	1% Fe	<2.5	<2.5	<2.5	<2.5
30/50/70	1.45% 304 S.S.	<2.5	<2.5	<2.5	<2.5

SULFURIC ACID

Sulfuric acid is undoubtedly the most important raw material in the chemical and pharmaceutical industry today. This fact is not unique to the United States, but is true on a worldwide basis. One can often look to the production and/or use of sulfuric acid as an indication of the industrial activity of a nation. Few chemicals are manufactured without sulfuric acid being involved. It is a strong dibasic acid and can be a reducing acid, an oxidizing acid, and/or a dehydrating agent.

In the chemical industry, sulfuric acid has many diverse applications. The largest quantities are used to manufacture phosphate and nitrogen based fertilizers. The petrochemical sector utilizes sulfuric acid in alkylation and paraffin refining. The inorganic branch of the chemical industry uses sulfuric acid in the production of chromic and hydrofluoric acids, aluminum sulfate and sodium sulfate. The organic arm employs sulfuric acid in the manufacture of explosives, soaps, detergents, dyes, isocyanates, plastics, pharmaceuticals, etc. Everywhere one turns today, we encounter products which use sulfuric acid in their manufacturing process.

Many chemical plants use sulfuric acid in one or more process steps and this generally results in severe corrosion problems. Each process has unique minor constituents that can change the way metals corrode. Zirconium has been used very successfully in many sulfuric acid applications. The advantage of zirconium is that corrosion rate will be very small if properly applied and equipment life of over 20 years is expected. Since there is no corrosion maintenance, repair, downtime and replacement costs do not exist and will quickly pay back for the slightly higher initial cost.

Corrosion Resistance of Zirconium Vs. Other Materials in Sulfuric Acid

		CORROSION RATE (mpy)				
CONCENTRATION (%)	TEMP. (°C)	Zr 702	310L S.S.	316L S.S.	Alloy B-2	Alloy C-276
10	102*	<0.1	45	574	<1	7.0
30	108*	<0.1	1,137	5,000	2	55
55	132*	0.1	350,000	10,000	1.89	295
55	168	19.6	—	—	37	212
2	225	<0.1	—	—	14.9	39.7
5	232	0.1	—	—	110	153
10	225	0.1	—	—	1,023	661

*Boiling point **Heat treating of zirconium weldments may be required for sulfuric acid.

ACETIC ACID

Acetic acid is one of the basic components in a wide range of organic materials including acetate esters, acetic anhydride, terephthalic acid, aspirin and other pharmaceuticals. Zirconium is considered the most corrosion resistant material in virtually all acetic acid solutions. The few exceptions include acetic acid containing cupric ions, free chlorine and solutions with insufficient moisture to allow zirconium to reform its protective oxide surface layer. Under highly stressed conditions, >650-ppm water is required in acetic acid to prevent stress corrosion cracking. If water addition is not practical, stress relieving may be considered.

Corrosion Resistance of Zirconium in Acetic Acid

MEDIA	CONCENTRATION (%)	TEMPERATURE (°C)	CORROSION RATE (mpy)
Acetic Acid (amhydride)	99	Room – boiling	<1
Acetic Acid	5 – 99.5	35 – boiling	<1
Acetic Acid	99	200	<1
Acetic Acid (glacial)	99.7	Boiling	<1
Acetic Acid (glacial) + 0.5% methanol	99	200	<1
Acetic Acid (glacial) + 0.5% methanol + 200 ppm $FeCl_3$ + 1% H_2O	98	200	<1
Acetic Acid (glacial) + 200 ppm $FeCl_3$	99	200	<1
Acetic Acid + 0.5% methanol + 200 ppm $FeCl_3$ + 5% H_2O	94	200	<1
Acetic Acid + 1% I^-(KI) + 100 ppm Fe^{+3}($Fe_2(SO_4)_3$)	99	200	<1
Acetic Acid + 10% methanol	90	200	<1
Acetic Acid + 10% methanol + 200 ppm $FeCl_3$ + 1% H_2O	88	200	<1
Acetic Acid + 10% methanol + 200 ppm $FeCl_3$ + 5% H_2O	84	200	<1
Acetic Acid + 10% methanol + 1000 ppm copper Acetate	89	89	<1 pit
Acetic Acid + 10% methanol + 1000 ppm Cupric Chloride	89	89	<1 pit
Acetic Acid + 10% methanol + copper metal	89	89	<1 pit
Acetic Acid + 1000 ppm copper Acetate	99	115	<1 pit
Acetic Acid + 1000 ppm copper metal	89	115	<1 pit
Acetic Acid + 1000 ppm Cupric Chloride	89	115	<1 pit
Acetic Acid + 2% HI	80	100	<1
Acetic Acid + 2% HI	98	150	<1
Acetic Acid + 2% HI + 1% methanol + 500 ppm formic acid	80	150	<1
Acetic Acid + 2% HI + 1000 ppm copper Acetate	97	115	<1 pit
Acetic Acid + 2% HI + 1000 ppm copper metal	97	115	<1 pit
Acetic Acid + 2% HI + 200 ppm Cl^-(NaCl)	80	100	<1
Acetic Acid + 2% HI + 200 ppm Fe^{+3}($FeCl_3$)	80	100	<1
Acetic Acid + 2% HI + 200 ppm Fe^{+3}($Fe_2(SO_4)_3$)	80	100	<1
Acetic Acid + 2% HI + 1% methanol + 500 ppm formic acid + 100 ppm copper	80	150	<1
Acetic Acid + 2% I^-(KI)	98	150	<1
Acetic Acid + 48% HBr	50	115	<1
Acetic Acid + 50% Acetic Anhydride	50	Boiling	<1
Acetic Acid + 50 ppm I^-(KI)	100	160,200	<1
Acetic Acid + HCl bubble	98	21	<1 pit
Acetic Acid + HCl bubble + chlorine bubble (liquid & vapor)	98	102	>50
Acetic Acid + Saturated, gaseous HCl and Cl_2	100	Boiling	>200
Acetic Acid + Saturated, gaseous HCl and Cl_2	100	40	<1
Acetic Acid + 1% acetyl chloride	99	Boiling	>50
Acetic Acid + 0.1% acetyl chloride	99	Boiling	wg
Acetic Acid + 200 ppm acetyl chloride	99	Boiling	wg

FORMIC ACID

More corrosive than acetic acid, formic acid is used in the production of pharmaceuticals, dyes and artificial flavors. The leather, textile, rubber, and pulp and paper industries also use formic acid in their process.

Corrosion Resistance of Zirconium in Formic Acid

MEDIA	CONCENTRATION (%)	TEMPERATURE (°C)	CORROSION RATE (mpy)
Formic Acid	10 – 98	35 – boiling	<1
Formic Acid (aerated)	10 – 90	Room – 100	<1
Formic Acid + 5% sulfuric acid	50, 70, 93	Boiling	<1
Formic Acid + 5% hydrochloric acid	50, 70, 85	Boiling	<1
Formic Acid + 1% Cupric Chloride	50, 70, 96	Boiling	<1
Formic Acid + 1% iron powder	50, 70, 98	Boiling	<1
Formic Acid + 5% HI	50, 70, 90	Boiling	<1
Formic Acid + 2% hydrogen peroxide	50	80	<1
Formic Acid + 4% hydrogen peroxide	50	80	<1

Corrosion Resistance of Zirconium in Various Media

MEDIA	CONCENTRATION (%)	TEMPERATURE (°C)	CORROSION RATE (mpy)
Acetaldehyde	100	Boiling	<2
Acetyl Chloride	100	25	>200
Aniline Hydrochloride	5, 20	35 – 100	<1
Aniline Hydrochloride	5, 20	100	<2
Bromochloromethane	100	100	<2
Dichloroacetic Acid	100	Boiling	<20
Ethylene Dichloride	100	Boiling	<5
Formaldehyde	6 – 37	Boiling	<1
Formaldehyde	0 – 70	Room – 100	<2
Formalin	100	98	<1
Hydroxyacetic Acid	70	205	<1
Methanol + 0.1% KI + 0.1% formic acid	99.8	65	Nil
Melamine	100	260	<1
Melamine	100	427	<1
Methanol + 1% KI	99	200	<1
Oxalic Acid	0 – 100	100	<1
Oxalic Acid + 52% sulfuric acid	4	82	<1
Oxalic Acid + 52% sulfuric acid + 3% nitric acid + 2.5% ferrous sulfate	4	82	Gained Weight
Phenol	Saturated	Room	<5
Phenol + 11% hydrochloric acid	60	70	<1
Phenol + 27% hydrochloric acid	7.2	100	<1
Sodium Formate	0 – 80	100	<2
Sodium Phenolsulfonate	100	185	<1
Tannic Acid	25	35 – 100	<1
Tartaric Acid	10 – 50	35 – 100	<1
Tetrachloroethane	100	Boiling	<5
Trichloroethylene	99	Boiling	<5
Urea	50	Boiling	<1
Urea Reactor Mixture—45% urea, 17% ammonia, 15% carbon dioxide, 10% water	Mixture	193	<1