How to Select the Proper Alloy For Glass and Ceramic Seals

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Metals are beginning to play ore important roles in electronics applications.

Properly designed, a suitable etal seal will insure longer fe to the component.

There are a growing number of pplications where metals have to rm a perfect seal with glass and ramics. Vacuum tubes, transrmers, high-voltage lamps, insulars, mercury switches are just a few.

The prime requisite in designing ight seal is to prevent undue ains set up in the glass or ceramic upon cooling from the sealing temperature. Close matching of the thermal expansions and contractions of the glass and metal minimizes these strains.

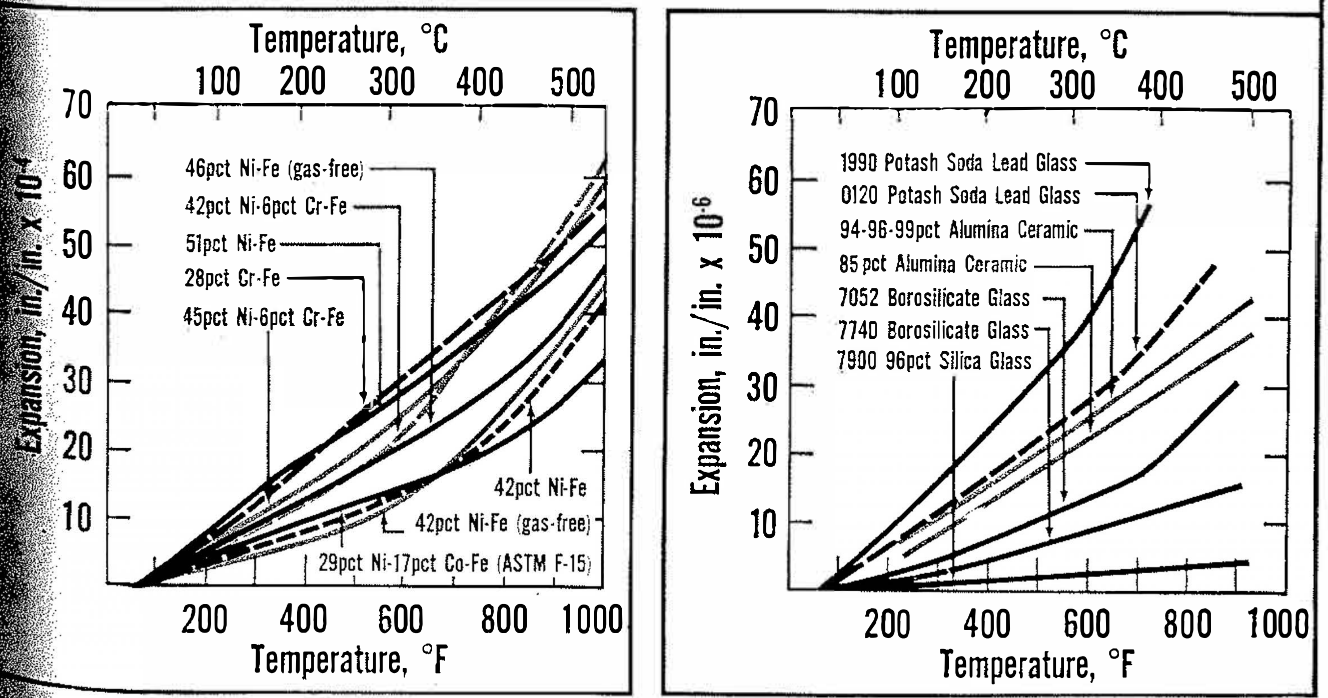
Most structural metals, including copper, aluminum and silver, have much higher expansion traits than glass or ceramics. This difference in expansion makes it difficult to join such metals to glass and keep the glass from cracking when the assembly is heated and cooled in service.

Case of the Lamp—A high-wattage lamp is a good example of the problem. In this case, two metal conductors must go through the Pyrex glass, leaving a vacuum-tight seal.

Copper is the ideal conductor. But even if it were possible to pass a copper wire through the glass and seal it, the glass would crack at the seal the first time it is heated. Why? Because of the high stresses built up by the difference in expansion.

If this lamp were heated to 300°F in service, the stress developed in the glass at the seal would be 30,000 psi. This stress is much more than glass can take. But with the right glass sealing alloy, the maximum stress in the glass even when heated

Some Alloys Match Expansion Rates of Glass



to 900°F is only about 2000 psi. This is low enough for the glass to withstand without cracking. Good design can further relieve the stress.

Thermal Expansion—It would be ideal if the alloy used for sealing had the same thermal-expansion properties as the glass or ceramic. Unfortunately, exact duplication is very rare.

There are several nickel-iron alloys containing 41-52 pct nickel, however, which have expansion coefficients that closely match those of glasses and ceramics. Four more special alloys: a nickel-cobalt-iron alloy, a chromium-iron alloy and two nickel-chromium-iron alloys, also offer expansion rates close to those of certain important glass formulations.

Leading Candidate—Most popular of the sealing alloys is a 29 pct nickel-17 pct cobalt-iron alloy (ASTM F-15) with thermal expansion properties closely matching those of the harder glasses and ceramics.

This is a low-expansion alloy used for making vacuum-tight seals with the hard glasses. The expansion rate remains low up to about 815°F and closely matches that of several ceramics.

Chemical composition of the 29 pct nickel-17 pct cobalt material must be controlled within narrow limits to assure precise and uniform thermal expansion properties. It must be processed from ingot to finished size under strict quality control to provide uniform properties and easy deep drawing, stamping and machining.

Within the Limits—To make sure the alloy is kept within the minimum and maximum expansion limits, characteristics are determined on a specimen annealed at 1650°F for 30 minutes, then heated to 2010°F for 10 minutes, and slow cooled.

Furnace cooling should be used when evaluating expansion characteristics. If the specimen were air cooled, expansion properties would be lower than they would be at slower cooling rates.

Another important glass-to-metal sealing alloy is the 42 pct nickel-iron alloy used to seal a number of special electronic tubes, transformers and capacitor bushings. It may be used with hard glasses when employing a ring type or housekeeper-type seal with a feathered edge about 0.002 in. thick.

Copper-Clad Wire—A slight variation of the 42 pct nickel-iron alloy is used as the core of Dumet wire for leads in electron tubes and incandescent lamps. The Dumet wire, which is clad with copper to about 20 pct of the overall cross section, provides a good seal with soft glasses when used in diameters of about 0.008-0.040 in.

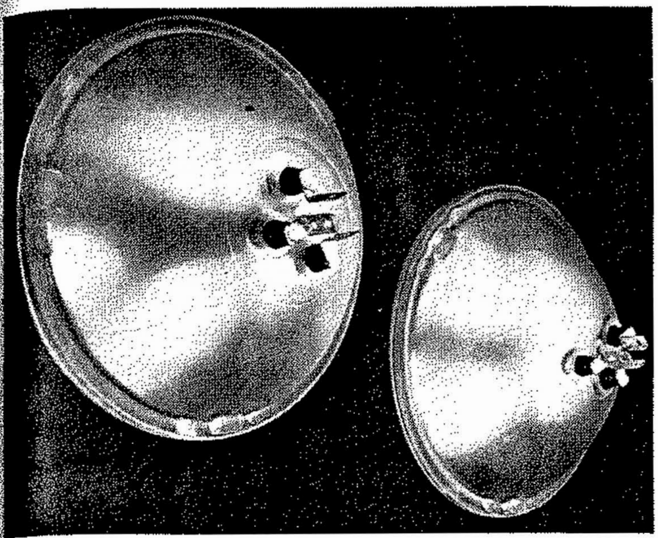
Another variety of this alloy proves useful too in making ferrules for passing a high current into a vacuum, using Pyrex glass.

A typical application is the ferrule sealed in the Pyrex glass on the back of a sealed beam headlamp. The ferrule forms a ring type

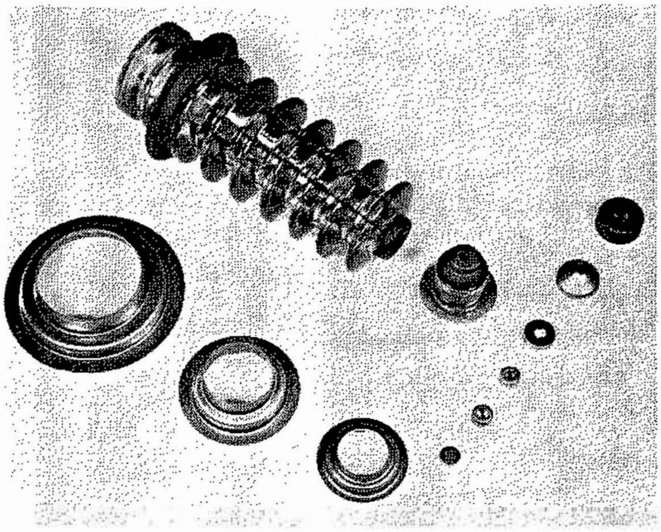
Property Rundown of Eight Alloys Aids Choice

Physical Constants:	42 pct Ni-Fe	42 pct Ni-Fe Gas Free	42 pct Ni-6 pct Cr-Fe	45 pct Ni-6 pct Cr-Fe	46 pct Ni-Fe Gas Free	51 pct Ni-Fe	28 pct Cr-Fe	29 pct Ni-17 pct Co-Fe (ASTM F-15)
Specific gravity	8.12	8.12	8.12	8.14	8.17	8.30	7.6	8.36
Density, lb/cu in.	0.293	0.293	0.294	0.295	0.295	0.30	0.27	0.302
Thermal conductivity,								
cal/cm³/sec/°C	0.025	0.025	0.029	0.029	—	0.032	0.054	0.04
BTU/hour/sq ft/°F/in.	74.5	74.5	87.0	87.0	—	97	158	—
Electrical Resistivity,								
microhms/cm³	72	72	95	95	46	43	63	—
ohms per cir. mil ft	430	430	570	570	275	258	380	294
Inflection Point, °F	650	—	650	680	—	1050	—	—
Curie Temperature, °F	715	715	—	—	860	—	—	815
Melting Point, °F	2600	2600	2600	2600	2600	2600	2600	2640
Specific Heat	0.12	0.12	0.12	0.12	0.12	0.12	0.14	—
Mechanical Properties: (as annealed)								
Tensile strength, psi	82,000 120,000*	80,000	80,000	80,000	82,000	80,000	85,000	75,000
Yield strength, psi	—	34,000	40,000	40,000	34,000	40,000	55,000	50,000
Elongation in 2 in., pct	30 3*	30	30	30	27	35	25	30
Hardness, Rb	76 100*	76	80	80	76	83	85	68
Elastic modulus, psi x 10^{-6}	21.0 21.0*	21.0	—	—	23	—	—	20

* Values for cold drawn bars and cold rolled strip.



HEADLIGHT: Hard glass for a sealed-beam headlight is sealed by a ferrule of the 42 pct Ni-Fe alloy.



METAL GROMMETS: The expansion limit range is narrow for alloy grommets in high-voltage bushings.

seal. Although the alloy does not match the glass too well, the stresses are absorbed by the thin cross section of the metal. Tapering the seal edge helps to relieve the stresses.

Suitable Sealer—A 42 pct nickel-6 pct chromium-iron alloy has thermal-expansion properties suitable for sealing with soft glasses and the 0010 and 0120 glasses.

The tendency of this nickel-chromium-iron alloy to form a chrome oxide during heat treatment provides advantages in making terminals which must be vacuum tight and withstand twisting and other stresses. A good glass-to-metal seal is possible due to the fact that the chrome oxide is soluble in the glass when the glass-to-metal match is good.

Higher Nickel—There is a 45 pct nickel-6 pct chromium-iron alloy which is better suited to the 9010 glass than the 42-6 alloy because of closely matching expansion rates. The 45-6 alloy has about the same expansion coefficient at 752°F as the 42-6 alloy. But in the temperature range of 400°-575°F, the expansion characteristics of the 45-6 alloy are higher than those of the 42-6 alloy.

Like the 42-6 alloy, the 45-6 steel is also suitable for sealing with the 0010 and 0120 glasses. The 45-6 alloy also produces the dark-green oxide coating conducive to a good glass-to-metal seal when heat treated in certain atmospheres.

A 51 pct nickel-iron alloy can be used to make many direct glass-to-metal seals with some soft glasses. It can also be used for terminals using 1010 grommets.

Easy to Clean—Though these seals are not as strong as the terminal seals of the 42-6 alloy, the 51 pct nickel grade is easy to acid clean for plating after the seals are made.

A 28 pct chromium-iron alloy provides a very good match for soft glasses such as lead glass and lime glass. It is a ductile alloy used in Lumiline lamps and Circline lamps. In some cases, it can be used to advantage in special electronic devices and vacuum tubes.

There is still another important glass sealing alloy. This one is a 46 pct nickel-iron alloy designed for enamel coating, glass-to-metal sealing and ceramic-to-metal sealing.

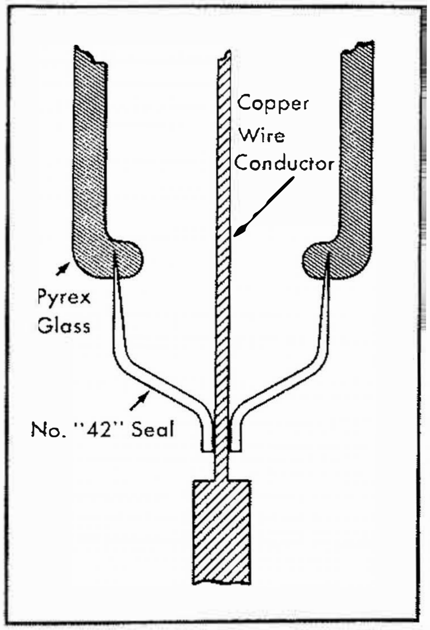
Gas Pockets—One problem encountered in making glass-to-metal seals is the tendency for gas pockets to develop between the glass and metal. When gas is present, little bubbles are likely to form at the glass-to-metal interface.

Result: Subsequent cracking at the seal. Under such conditions, it's impossible to get the air-tight seal required for many jobs.

Gas is caused by a chemical reaction in the sealing process. Iron-nickel alloys, containing no chromium, tend to eject carbon monoxide and carbon dioxide when heated. This emission can be eliminated by decarburizing the surface of the part, by keeping carbon content low, or by tying up the carbon by forming a stable carbide.

The Oxide Film—All glass sealing alloys form an oxide film during heat treatment—either in the special preoxidizing treatment or in the sealing process.

Chrome oxide is the best film for

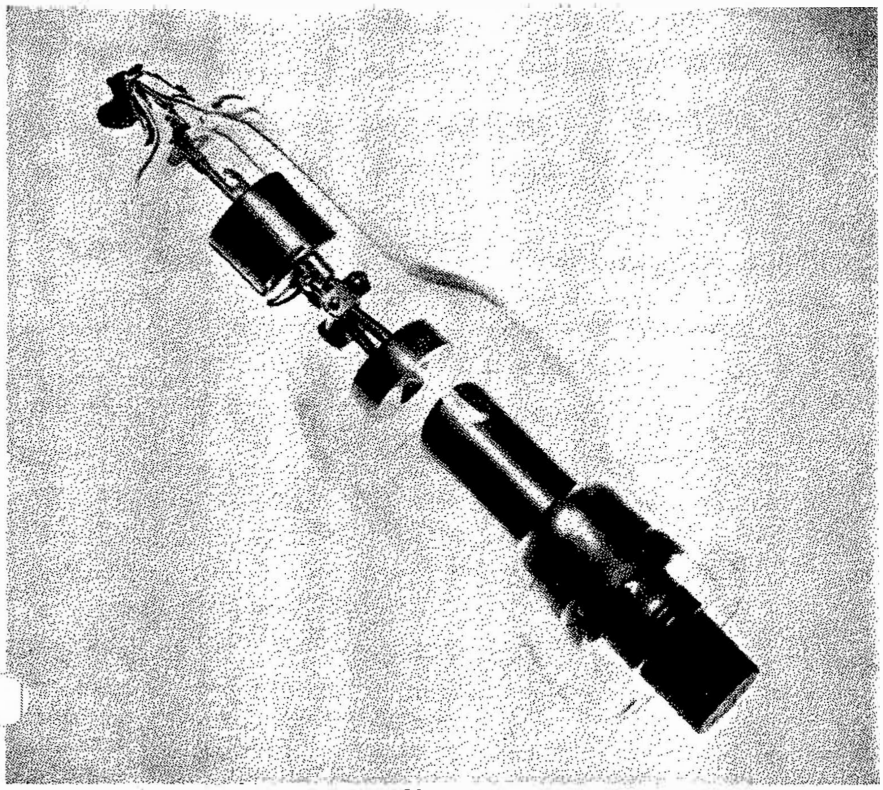


TAKES HEAT: Suitable metal conductors going through Pyrex glass keeps lamps going at high heat.

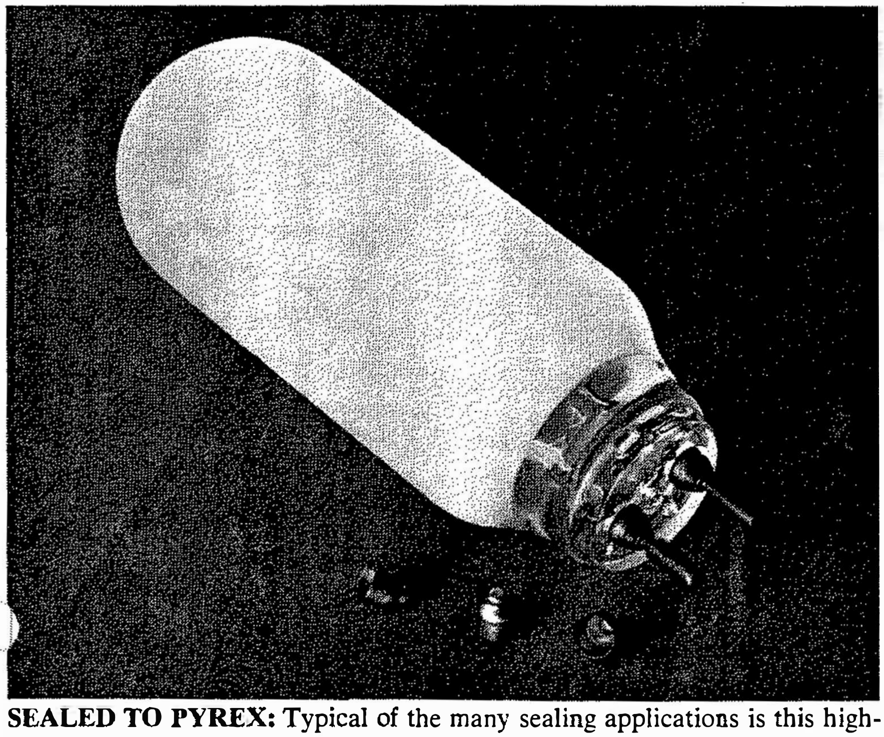
sealing because it is the most tightly adhering to the base metal. The film is caused by a reaction between the metallic surface oxide and silica.

A strong tenacious oxide is produced on the surface of the 42-6 alloy by proper heat treating. In fact, the bond holding the parent metal and glass together at the seal can be stronger than the glass.

To produce a good, tightly-adhering oxide on this type of alloy, the part must be mechanically cleaned to remove any passivated film.



X-RAY TUBE: This high-voltage X-ray tube is typical of the many types of tubes that require a vacuum-tight glass-to-metal seal.



SEALED TO PYREX: Typical of the many sealing applications is this high-wattage lamp. Metal conductors must be sealed to Pyrex glass.

Hydrogen-Free—A wet cracked ammonia atmosphere can be used with hydrogen bubbling through water and into the furnace. The temperature used for oxidizing depends upon the type of furnace, muffle and thermal cycle used.

The temperature should be at least 1900°F but no higher than 2350°F. The time at heat can vary from 30 minutes at maximum temperature to one hour at lowest temperature. The oxide film for the 45 pct nickel-6 pct chromium alloy is formed in much the same way.

For most applications, the 28 pct chromium-iron alloy requires no oxide coating. But a suitable oxide can be produced on the metal by preheating in a gas flame. A tight adhering oxide results.

Seal Design—After the alloy is selected which most closely matches the expansion rate of the glass to be used, the seal must be carefully designed so that it remains airtight.

One technique is to use thin sections of feathered edges where the metal is imbedded into the glass. This approach works well in sealing to the harder, lower-expansion glasses.

Likewise, tapering the edge of the glass-to-metal seal permits the metal to bend elastically, thus relieving stress. Even when the match coefficient is not perfect, the metal in the well-designed seal will give instead of break as will the glass.

All of the basic sealing alloys are available in various forms including cold rolled strip, cold drawn wire, and bars either hot rolled, cold drawn or centerless ground.

Generally, strip is purchased in deep-drawn condition with surface free of any oxides. It can be annealed with either a bright and clean finish or annealed for deep-drawing applications. Several alloys are available in billet form for forgings.

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