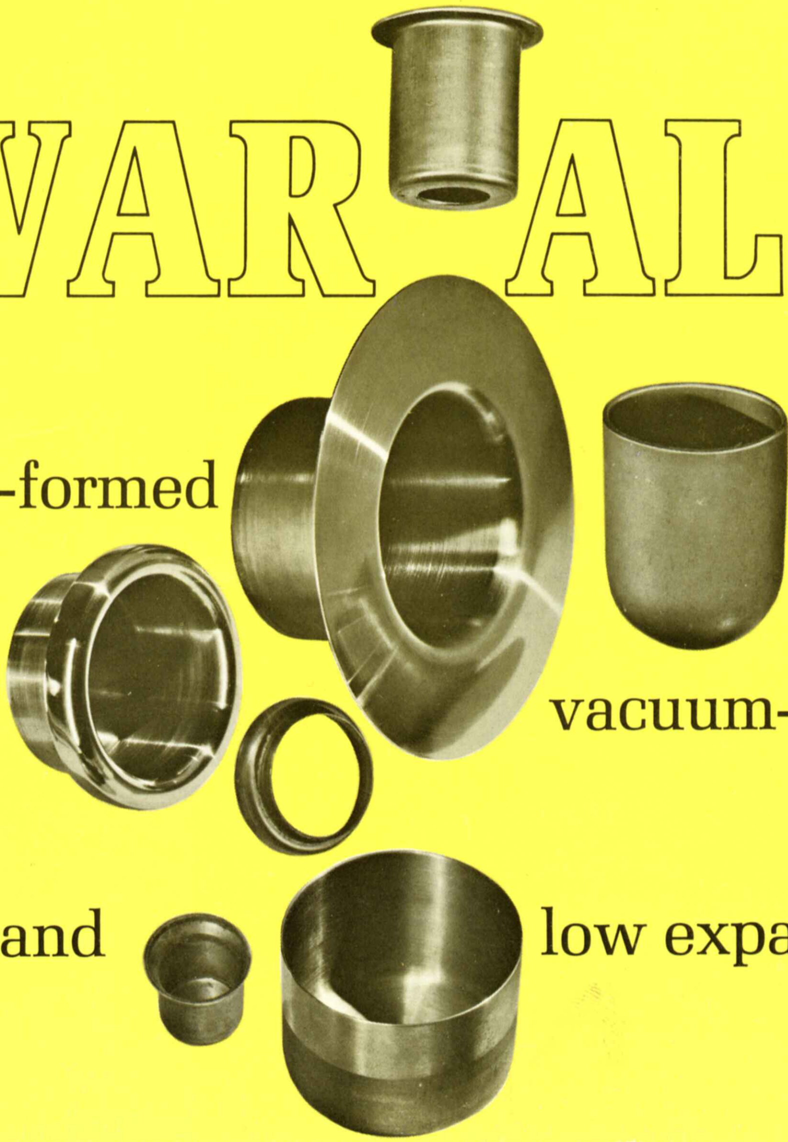
CARBORUNDUM®

KOVAR ALLOY



makes easily-formed highly-reliable pressure and vacuum-tight seals with hard glasses and low expansion ceramics

KOVAR®

*KOVAR's thermal expansion rate is the key property that makes this alloy useful. Unlike most metals, it expands at a variable rate with increasing temperature. Also, its change of dimension is relatively small.

The expansion curve of KOVAR, an iron-nickel-cobalt alloy, matches almost perfectly the corresponding curves of several hard glasses. This alloy has an inflection point at the critical annealing point of the glass, whereas most metals have expansion curves approaching a straight line.

As KOVAR expands only slightly more than selected ceramic bodies, such as 96% alumina, it assures a strong joint under compression.

Seals and glass-to-metal bonded assemblies of these matching materials can be made with a minimum of locked-in stresses.

Furthermore, as matched assemblies and seals are called upon to serve over a wide, useful temperature range, the metal and glass expand and contract together. With thermal stresses eliminated, service life is prolonged and reliability substantially increased.

Easy sealing to glasses is another feature that makes KOVAR attractive. It provides a chemically-fused joint that does not depend upon pressure for perfect sealing.

This pioneer alloy for matched-expansion sealing was developed in the 1930s and is still the preferred metal for this purpose. Early development work was done by Westinghouse Electric Corporation and the registered trade mark, KOVAR®, is still owned by Westinghouse.

Fabricating, service and engineering work on applications of KOVAR are handled by the Electronics Division of Carborundum from the Latrobe, Pa. Plant. These areas of activities can only be touched upon in this bulletin. Supplemental data sheets that give information on ranges of shapes, problem solutions, new developments etc. are available to you. Experienced engineers will provide technical assistance whenever desired.

The need for perfectly-bonded joints between metals and glasses or ceramics is encountered in a number of fields. Most common is the situation where an electrical conductor must be brought into an evacuated or hermetically-sealed metal container. Here, a glass bushing—sealed both to the conductor and to the metal around it—insulates the conductor from the case. Manufacturers of metal electron tubes use KOVAR in this way.

Another occasion arises when a sight glass or window is desired in the wall of a hermetically sealed vessel.

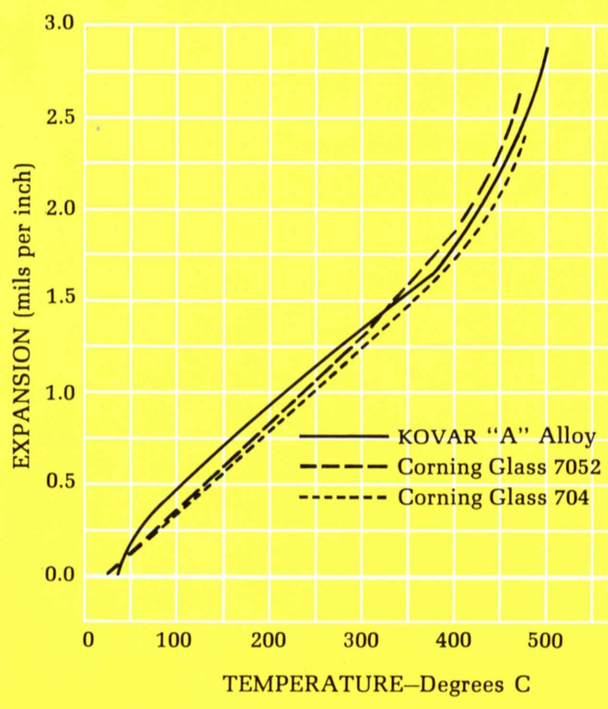
In laboratory work, it is often desirable to have metal and glass apparatus fused together—for example, to put a metal-electrode section into a length of glass tubing.

Insulating seals for electrical equipment are employed in many more kinds of components than just the electron tube. A vacuum or gas-filled tube, of course, does not function as it should unless it is perfectly sealed.

Other devices—semi-conductors, capacitors, relays, transformers, crystals, resistors, etc.—are far more reliable when enclosed in hermetically-sealed cases—either containing dry air or a gas under suitable pressure. Sometimes it is advantageous to seal off entire circuits, subassemblies or functional units of apparatus in these containers. What is gained by hermetic sealing is freedom from the troubles and failures caused by dirt, dust, moisture, fungus or lack of atmospheric

X-Ray tube with KOVAR-glass seal and tungsten-embedded copper casting that has been silver brazed to a KOVAR cup.

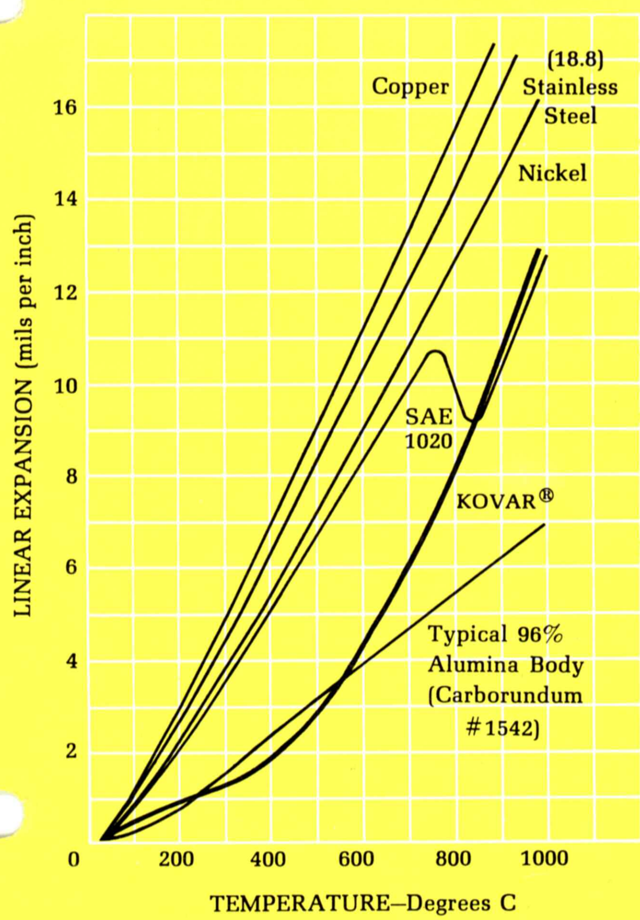
Comparative thermal expansion curves show how clo[illegible] KOVAR alloy corresponds to two hard glasses. Matched assemblies and seals of these materials serve over a wide temperature range because the components expand and contract together. Moreover, the likelihood of creating tensional stresses in the glass is minimized.



ALLOY

where it's used and why

Linear expansion curves of typical materials employed for sealing purposes at elevated temperatures.



pressure at high altitudes. Engineers are, therefore, using this protection method more and more wherever reliability is important.

The cost of hermetic sealing and the provision of sealed, insulated electrical leads to accommodate all circuits has proved to be a modest and entirely reasonable investment compared to the much greater reliability that such an enclosure can yield.

A fused joint does not depend upon pressure or mechanical bonding for effective sealing, even under widely variable operating conditions. The insulating and conducting materials are fused together for true chemical or molecular bonding. This is the type of joint formed between KOVAR and hard glass; it is impractical or else very difficult to achieve without close matching of thermal-expansion characteristics.

Thermal shock and high-temperature operation usually demand the use of shock-resisting "hard" glass of the borosilicate type for sealing electrical units. It is for matching with certain types of these glasses that KOVAR was specifically developed.

Certain other sealing metals have a close enough match in thermal expansion to be used for hermetic-sealing with hard glass. Generally, they present difficulties, however, from a practical standpoint. Tungsten, for example, presents severe limitations in workability. Molybdenum may be formed in careful stages, but the oxide on its surface is difficult to control for making a good hermetic seal. Both of these metals, of course, are relatively costly.

KOVAR, on the other hand, is easily formed into intricate shapes and can be welded, soldered and brazed to other metals without difficulty.

Ease of sealing hard glass to KOVAR is an important feature. An oxide surface forms on the alloy's face when it is heated in air. Glass, heated to the plastic working temperature range, bonds readily to this hot-oxide surface.

The ease with which KOVAR can be processed results in high production yields. Savings thus obtained frequently are greater than might be gained from the use of less costly alloys.

In joining glass to metal heat is usually applied by oxy-natural gas or oxy-hydrogen flames with the parts sealed on glass-working lathes or on conventional automatic-stem machines. Either induction heating or special furnaces can be employed if desired. With appropriate tooling, full advantage can be taken of economical mass-production techniques. Seal manufacture, incidentally, is often automated.

Joining KOVAR to other metals—brazing, welding, soldering—all common methods are readily practical. And tinning or plating with other metals can be accomplished by usual procedures.

Low thermal conductivity of KOVAR permits brazing close to the glass seal by induction heating.

Proven success of KOVAR seals in many kinds of arduous service—and of the sealing process itself from the standpoints of economy and practicability—gives you assurance on which you can base plans for new applications. Skilled engineers at our Latrobe Plant (formerly the Stupakoff Division) will be glad to help you solve sealing or expansion-matching problems that KOVAR can handle.

*All data herein are based on the metal designated as KOVAR "A" alloy. KOVAR is a registered trademark (337962) of Westinghouse Electric Corporation.

How to handle, form and machine Kovar® Alloy

There is nothing especially fragile or sensitive about KOVAR metal as you receive it. True, carefully-controlled conditions are maintained in producing this special iron-nickel-cobalt alloy. Furthermore, strict precautions have to be observed during the manufacture of high-quality seals to control cleanliness, surface finish, gas content and internal stress.

To store KOVAR alloy a dry, clean room should be used. Where possible, it is recommended that the parts be wrapped.

Forming properties of KOVAR alloy are slightly better than those mild steel displays. Sheet, as furnished, is annealed. By successively deep drawing with reduction of 40%, 25% and 20%, a cup's length approximates 1½ times its diameter before an intermediate anneal is needed.

All the common metal-forming processes can be used. A word of caution about spinning—it is difficult to inspect for minute fractures that might occur in spinning. These fractures may result in vacuum leaks. For this reason, spinning is confined mainly to model work with frequent anneals, and special care is devoted to inspection.

For annealing and stress relieving KOVAR alloy, furnaces preferably should be equipped to provide a hydrogen atmosphere. A neutral atmosphere can be used for annealing during forming if the parts are hydrogen-annealed just prior to sealing.

Machining practice for KOVAR alloy is much like that for Monel "R" Metal. Use ample coolant, relatively slow speeds and tools of high-speed steel or tungsten carbide.

Grinding and polishing techniques are no different from conventional metals. Edges of the alloy-sealing surfaces should be well rounded because sharp edges result in points of stress concentration. An essential precaution is to eliminate longitudinal draw and tool marks. Glass-sealing surfaces do not require a high degree of polish; a slight roughness as attained with Aloxite® (aluminum oxide) abrasive cloth of medium grit or sandblasting, in fact, is desirable.

KOVAR wire .035-inches diameter and under is drawn through diamond dies which avoids the need for additional polishing. Larger diameters are available as centerless ground straight rods. These are free from drawing and straightening marks, and give material ready for the most exacting high-vacuum type seals. For less critical applications, rod and wire in as-drawn finish are more economical.

Cleaning of KOVAR alloy parts before they go to the sealing operation is essential. All contamination should be removed from the metal surfaces.

Degassing and annealing in a wet hydrogen atmosphere are accomplished as a final operation immediately before sealing. A typical degassing program is conducted at 1000 C (1832 F) for 30 minutes.

Parts coming from the cooling zone should be protected from all dirt and grease. They should not be touched with bare hands. Ideally, they should go to the sealing operation within an hour or two, otherwise the parts should be protected from atmosphere contamination.

THERMAL EXPANSION SPECIFICATIONS

After annealing in hydrogen for one hour at 900 C and for 15 minutes at 1100 C, the average linear coefficie[illegible] shall fall within the following limits:

Temperature Range	Average Lineal Coefficient of Thermal Expansion (cm/cm/°C x 10^{-6})
30 - 400 C	4.54 - 5.08
30 - 450 C	5.03 - 5.37

Typical expansion data for other temperatures are as follows:

Temperature Range	Average Lineal Coefficient of Thermal Expansion (cm/cm/°C x 10^{-6})
30 - 200 C	5.04
30 - 300 C	4.86
30 - 400 C	4.74
30 - 500 C	6.19
30 - 600 C	7.89
30 - 700 C	9.31
30 - 800 C	10.39
30 - 900 C	11.47

TENSILE PR

Typical values listed in the table below represent re[illegible] ol

Specimens	Temp. of Test. °C	0.5% Yield Strength, PSI	Ultimate Strength, PSI
1	21	59,500	77,500
2	213	39,000	58,500
3	308	32,500	54,500
4	400	30,000	50,000
5	500	26,500	42,000
6	600	23,500	36,000
7	738	21,500	25,000
8	790	17,100	19,000

ELECTRICAL PROPERTIES

Specific resistance at 25 C—49 microhms cm (294 ohms/cir mil ft)

°C	Relative Resistivity
25	1.00
100	1.28
200	1.64
400	2.19
600	2.38

PHYSICAL CONSTANTS

Density	0.302 lbs./cu. in.
Annealed Temper (Rockwell Hardness)	B82 (max.)
Cold-Worked Temper (Rockwell Hardness)	B100 (max.)

CHEMICAL COMPOSITION	
Nickel	29% (nom.)
Cobalt	17% (nom.)
Iron	Remainder
Manganese	0.50% (max.)
Silicon	0.20% (max.)
Carbon	0.06% (max.)
Aluminum	0.10% (max.)
Magnesium	0.10% (max.)
Zirconium	0.10% (max.)
Titanium	0.10% (max.)

The total of aluminum, magnesium, zirconium and titanium shall not exceed 0.20%.

THERMAL PROPERTIES	
Melting point	1450 C
Thermal conductivity (cal/sec/cc/°C @ 30 C)	.0395
(cal/sec/cc/°C @ 300 C)	.0485
Curie point	435 C
Specific heat (cal/gm/°C @ 0 C)	0.105
(cal/gm/°C @ 430 C)	0.155
Heat of fusion (cal/gm)	64
Vapor pressure (microns @ 1000 C)	10^{-2}
Transformation point (gamma to alpha phase)	Below minus 80 C

)PERTIES

ain t various temperatures with a strain rate of 800%/hr.

Breaking Strength, PSI	Uniform Elong. %	Total Elong. %	Red. of Area %
44,000	16.78	35.4	69.0
37,500	18.59	32.08	73.2
37,500	22.12	34.79	65.2
31,000	20.90	36.33	74.0
29,000	21.69	33.96	71.0
32,500	19.45	28.40	35.0
22,000	6.87	18.23	25.0
15,000	5.21	14.65	21.6

MAGNETIC PROPERTIES

Magnetic Permeability	Flux Density (Gausses)
1000	500
2000	2000
3700	7000 (max. value)
2280	12000
213	17000

Magnetic Losses (Watts per Lb)

Thickness	10 Kilogausses 60 Cycles Sec.	10 Kilogausses 840 Cycles Sec.	2 Kilogausses 5000 Cycles Sec.	2 Kilogausses 10,000 Cycles Sec.
.010	1.05	23.4	16.6	41.0
.030	1.51			
.050	2.77			

Note: The values of the various properties are to be considered as nominal except where limits are shown.

How to make a Kovar seal with hard glass

The glass tubing or cane (Corning's 705-2, for example) is cut and cleaned by conventional methods—with considerable care to avoid dust on surfaces or abrasive inclusions from cutting wheels employed.

The KOVAR metal parts are first oxidized to provide surfaces that will bond readily to glass. Often this is done as part of the heating operation prior to sealing. All that is needed to heat parts to over 650 C (1202 F) is a slightly oxidizing flame.

The sealing operation involves bringing a plastic piece of glass at about 850 C (1562 F) against heated-oxide surfaces of the KOVAR alloy parts. Glass wets the metal oxide.

Slight pressure may be exerted on the plastic glass by flame impingement or with clean mechanical tools. The final contour of the glass can be controlled by placement of heating flames, by mechanical working, and by the shape of the glass bead or slug provided for heating at the beginning.

A seal between KOVAR and a glass of non-matching expansivity can be made by using a series of intermediate glasses. The order, for example, might be KOVAR and the following Corning glasses: 705-2 or 705-5, Uranium or cobalt and 774 Pyrex.

After the seal is formed, the assembly is cooled slowly to room temperature. The time-temperature program anneal should be adjusted according to seal size and glass used.

Oxide on exposed metal parts can now be removed by pickling. For making subsequent welded, brazed or soldered joints, either a bright KOVAR alloy or a plated or tinned surface finish may be used, if desired.

How to make a seal with ceramics

Equipment that must operate at temperatures above the service range of hard glass can be hermetically sealed using ceramic materials as the insulating medium.

Certain low expansion ceramic materials—especially those of the 96% alumina type—can be used with KOVAR to make excellent seals, preferably with the alloy being outside of the ceramic.

The process starts with metallizing the joint surfaces on the ceramic piece, either by spray techniques or by vacuum-deposition methods. Then, the KOVAR parts can easily be brazed to the metallized surface. An intimately-bonded hermetic seal results.

How to join Kovar® to other metal parts

KOVAR alloy, of course, often serves as a middleman—an intermediate material between glass or ceramics and some other metal. In this role, it must be joined to the other metals in such a manner as to provide vacuum-tight joints.

Most common joining methods can be used, but joints usually are made by brazing, resistance welding or—on "exterior" connections—by soldering the metal parts.

Whether the metal is joined first or after the glass seal has been made will influence the joining method selected.

In electron-tube work, for example, metal parts are often copper-brazed to KOVAR alloy, following which the glass seal is made. Mercury-vapor tubes have internal parts that are resistance welded to KOVAR before sealing with glass. These assemblies could not be made by brazing because the mercury would amalgamate with the brazing alloy.

After the glass seal has been made and the metal parts are cleaned of oxide, the choice of joining method depends upon costs and service requirements. The joint must be adequate for expected service temperatures and stresses, of course.

Situations to avoid include the introduction of volatile constituents into a vacuum tube or similar chamber. This rules out solder, fluxes or brazing alloys containing high vapor-pressure metals for interior joints.

Joints should be designed to minimize tensional stress on KOVAR alloy during brazing operations. Higher expansion member preferably should be on the outside to place the joint in compression. If essential to have this member on inside, adequate clearance must be allowed. This is especially important with silver brazing alloys because of stress corrosion effects.

Heating methods for making joints once the seal is made should take account of the fact that KOVAR alloy conducts heat faster than glass. Uneven heating can strain—and possibly break—the glass seal, even though the thermal-expansion coefficient of glass and metal are well matched. Thermal stresses from uneven heating, in addition, can subject portions of KOVAR to undesirable tensions.

High-frequency induction as a heating method has been very successful for making brazed joints—especially when the part to be heated is relatively inaccessible.

Induction heating, coupled with KOVAR's low thermal conductivity, permits making final brazed joints in close proximity to glass seal.

Torch brazing or use of a soldering iron is to be avoided due to undesirable effects of non-uniform heating. Sometimes, it helps to preheat the parts to lessen temperature gradients.

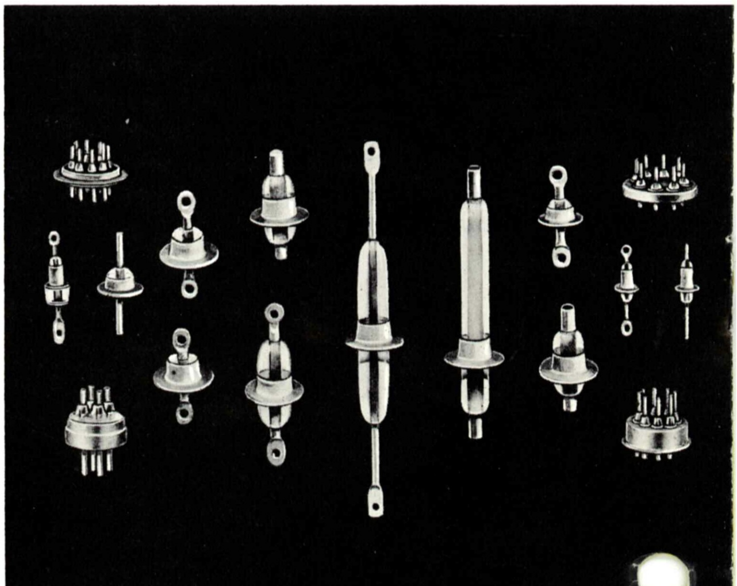
Continuous furnace brazing can be done in a reducing atmosphere with adequate provision for preheating and post-cooling. Also, parts can be brazed in a brazing bottle or similar container that affords rapid, yet uniform, heating and cooling.

A word about Kovar Alloy metallurgy

In manufacturing KOVAR, controls are exercised at various stages to assure close limits of thermal expansion and other desired properties. Among regular procedures to obtain uniformly high quality are tests for: thermal expansion, transformation, cupping for "drawability", Rockwell Hardness, grain size, freedom from gas and glass sealing. Rod and wire soundness is insured by subjecting the primary bar stock to ultrasonic testing and microscopic examination of the ends. Thorough inspection of sheets guards against surface defects.

KOVAR alloy is guaranteed not to undergo phase transformation from gamma to alpha at temperatures above minus 80 C (minus 176 F). Actual transformation is considerably lower. Where extremely low temperatures are service requirements, specially selected alloy melts with specific transformation points can be supplied.

KOVAR®



Typical KOVAR-glass seals made by terminal manufacturers to give pressure-tight sealing of devices that include transformers, relays etc.

CARBORUNDUM

stocks Kovar® Alloy in a wide variety of forms

You can get the best service to meet your KOVAR-alloy requirements from our Latrobe Plant because we carry the widest variety of forms, sizes and parts—in stock for immediate shipment.

The table on this page summarizes briefly the breadth and scope of our stocks. It does not, as you see, give specific sizes, however.

Data sheets are available to you for the asking with complete, up-to-date listings of stock items. Specifications, complete dimensions, surface finishes, tolerances and other details are covered thoroughly. Let us know your interest and your files will be kept current as stock items change.

Specials, too, can be supplied for those applications not served satisfactorily by stock items.

Regardless of your requirements, you will find Carborundum the kind of obliging, reliable source of supply with whom you like to do business.

scope of Kovar Alloy stock items

Form	Range of Stock Sizes	Notes
Strip	.001″ to .030″ x 6½″ wide	In coils, annealed for deep draw
Sheet	.010″ to .020″ x 6½″ wide x 72″ long .030″ to .125″ x 13″ wide x 72″ long	In flat lengths, annealed for deep draw
Wire	.005″ to .080″ diameter	Spooled or coiled
Rod	.040″ to .390″ diameter	"As drawn" finish, straight lengths
Ground Rod	.030″ to 3.0″ diameter	Centerless ground finish, straight lengths
Tubing	.030″ O.D. x .005″ wall to 1.125″ O.D. x .030″ wall	Seamless, "as drawn" finish, straight lengths
Cups	.360″ to 5.53″ O.D. x .020″ to .100″ wall	Drawn—flat or round bottom
Flanged Cups	.672″ to 3.375″ flange diameter x .020″ to .030″ wall	Drawn—straight or tapered sides
Flanged Eyelets	.220″ to 1.250″ flange diameter x .010″ to .020″ wall	Drawn—open ends straight or tapered sides

Details of standard sizes, price lists and quotations on non-standard items, including forgings, will be furnished on request.

THE CARBORUNDUM COMPANY
ELECTRONICS DIVISION • LATROBE PLANT
LATROBE, PENNSYLVANIA

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