100EB9-Issue 3
Sheet 1 of 5

PROPERTIES OF KOVAR® "A" ALLOY

THERMAL EXPANSION SPECIFICATIONS

After annealing in hydrogen for one hour at 900° C and for 15 minutes at 1100° C, the average linear coefficients shall fall within the following limits:-

Temperature Range	Average Linear Coefficient of Thermal Expansion (cm/cm/°C × 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 Linear Coefficient of Thermal Expansion (cm/cm°C × 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 PROPERTIES

Typical values listed in the table below represent results obtained at various temperatures with a strain rate of 800%/hr.

SPECIMENS	Temp. of TEST. °C	0.5% Yield Strength, PSI	Ultimate Strength, PSI	Breaking Strength, PSI	Uniform Elong. %	Total Elong. %	Red. of Area%
1	21	59,500	77,500	44,000	16.78	35.4	69.0
2	213	39,000	58,500	37,500	18.59	32.08	73.2
3	308	32,500	54,500	37,500	22.12	34.79	65.2
4	400	30,000	50,000	31,000	20.90	36.33	74.0
5	500	26,500	42,000	29,000	21.69	33.96	71.0
6	600	23,500	36,000	32,500	19.45	28.40	35.0
7	738	21,500	25,000	22,000	6.87	18.23	25.0
8	790	17,100	19,000	15,000	5.21	14.65	21.6

PROPERTIES OF KOVAR® "A" ALLOY

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%.

PHYSICAL CONSTANTS

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

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 – 80° C

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PROPERTIES OF KOVAR® "A" ALLOY

ELECTRICAL PROPERTIES

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

°C	Relative Resistivity
25	1.0
100	1.28
200	1.64
400	2.19
600	2.38

MAGNETIC PROPERTIES

Magnetic Permeability

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.

PROPERTIES OF KOVAR® "A" ALLOY

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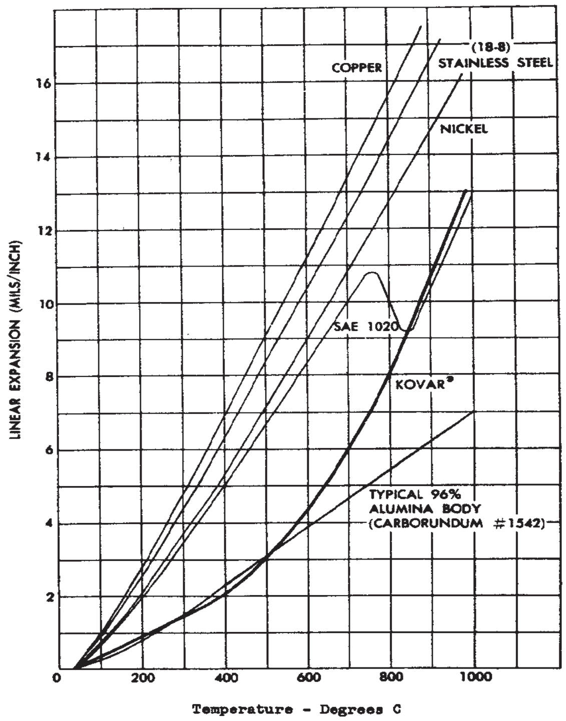

100EB5
Issue 2

THERMAL CONDUCTIVITY OF KOVAR® ALLOY

One of the notable properties of Kovar is its low thermal conductivity... 0395 calories per second per square centimeter per °C. per centimeter at 30°C.

This value is the result of careful measurement. Although actual measurements have not been made at elevated temperatures, such values may be calculated with reasonable assurance. Kovar is similar to iron and nickel with respect to resistance-temperature relationships. Therefore, in applying the Wiedemann-Franz - Lorenz law for the relation of thermal condustivity, temperature and electrical resistivity, it is entirely reasonable to use as a Lorenz factor for Kovar the average values for iron and nickel. When this is done, the following values are obtained:

	Temp. °C.	Thermal Conductivity	
Determined	30°	.0395±.001	cal. per sec. per cm²per °C per cm
Calculated	100°	.042	〃
〃	200°	.045	〃
〃	300°	.0485	〃
〃	400°	.053	〃
〃	500°	.0585	〃

A plot of the above values yields a curve which is almost parallel to the curve for stainless steel.

In the manufacture of standard Kovar "A" exacting control is maintained to insure keeping the thermal expansion within close limits. Although close tolerances are not guaranteed on the electrical properties, these are expected to be fairly uniform due to the close limits set on chemical composition.

Listed below are results of a typical test.

°C	Relative Resistance
25	1.00
100	1.28
200	1.64
300	1.97
400	2.19
500	2.31
600	2.38

(Typical specific resistance at 25°C – 49 microhm cm.)

100EB5
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(Typical specific resistance at 25°C – 49 microhm cm.)

METALLOGRAPHIC PROCEDURE FOR SAMPLE PREPARATION AND ETCHING OF KOVAR®

Sample Preparation :

1. Specimen is mounted in bakelite if size permits, or if edges need to be preserved.

2. Grinding is carried through 3-0 paper in the usual manner.

3. Polishing is done on an 85% wool, 15% silk, heavy-napped cloth (a Forstmann fabric, Burrell "Tan") using Line "B" polishing compound (Linde Air Products, Tonawanda, New York). This is the only polishing needed to give a smooth scratch-free surface. The powder is applied dry and water added to the wheel to make a paste. After smoothing the paste into the cloth it is ready to use.

   NOTE : If inclusions are to be preserved, a harder cloth should be used with an alumina-type polishing compound (Gamal cloth with Gamal alumina is very satisfactory, and may be purchased through Fisher Scientific Company, Pittsburgh, Pa.). This cloth is used in place of the above cloth, not in addition to it.

Etching

1. A saturated solution of water and ammonium persulfate is swabbed on the sample with cotton. Swabbing should be continuous, in fact, vigorous. Etching time varies considerably with the conditions of the metal, sometimes taking several minutes. Repolishing and etching two or three times will eliminate most of the surface metal distributed by the grinding operations. Of course, this also will eliminate most inclusions. No staining should occur after etching if the specimen is rinsed in alcohol before drying.
2. In those occasional cases of "obstinate etching," where the etchant has no apparent effect on the metal, aqua regia (80% HCl, 20% HNO_3) usually produces a satisfactory etch if it is swabbed on after the solution is at least 1/2 hour old. This etchant is faster-acting than ammonium persulfate; however, the staining which invariably accompanies aqua regia, when used on bakelite mounted specimens, makes it considerably more troublesome to use.

3. In some cases, it has been found, in order to obtain contrast a "Fry's etch" is used for 2 to 3 seconds on top of the ammonium persulfate solution. ("Fry's etch" is prepared by mixing 5 grams of copper chloride, 40 cc hydrogen chloride, 30 cc water and 25 cc ethyl alcohol.)

KOVAR® ALLOY-LOW TEMPERATURE CHARACTERISTIC

GENERAL

Kovar®, an alloy of iron, nickel and cobalt like other alloys of this general type, is subject to transformation at depressed temperatures. This phenomenon represents either a partial or total change from gamma to alpha crystalline structure, and is accompanied by a permanent increase in expansivity that may be sufficient to crack a glass seal.

SPECIFICATIONS

The specifications regarding transformation for standard Kovar® Alloy are as follows:

The temperature of the gamma-to-alpha transformation shall be below minus 78.5°C. However, for material whose smallest dimension is over 7/8″ (0.875), some localized transformation acceptable to the purchaser may be tolerated.

Further details of test procedure and illustration of transformed material are presented in 1961 A.S.T.M. Pre-print No. 68, Committee F-1 "Tentative Specifications Iron-Nickel-Cobalt Sealing Alloy."

ACTUAL TEMPERATURE OF TANSFORMATION

The temperature of minus 78.5°C has been selected for convenience, since this is the temperature resulting from an excess of dry ice in acetone. Production testing does not involve determination of the actual temperature of transformation of each heat.

Tests of a large number of production heats, however, indicate that the actual temperature of transformation is considerably below minus 78.5°C. On a special test of fourteen production heats, actual determination of transformation was as follows:

1. Six heats showed no transformation at minus 269°C.
2. Five heats showed partial transformation at minus 196°C.
3. Three heats showed partial transformation at minus 120°C.

KOVAR® ALLOY-LOW TEMPERATURE CHARACTERISTICS

ACTUAL TEMPERATURE OF TRANSFORMATION (Cont.)

The above indicates that for experimental purposes there is a good probability of making serviceable seals from stock Kovar® to operate at depressed temperatures without the costly and time consuming procedure of using specially selected hearts.

For production requirements, special lots of Kovar® can be supplied by either selection or special production to insure meeting customers' specifications of lower transfermation points than the standard guaranteed value (-78.5°C).

CONTRACTION AT DEPRESSED TEMPERATURES

Fig. I shows the contraction of one particular heat of Kovar® which partially transformed at minus 120°C. Fig. II shows the contraction of one particular heat which showed no transformation at minus 196°C.

No limits of contraction values have been establshed, nor do we know of any published data on stress values for Kovar®-Glass Seals at depressed temperatures. However, there are indications that for low temperature application serviceable seals may be made with thin sections of Kovar® even though the alloy might be partially transformed.

GENERAL

There is obviously a need for further basic studies on the behavior of Kovar® Glass Seals at depressed temperatures due to the increasing applications in this area. In the meantime, The Carborundum Company offers its services on specific customer problems.

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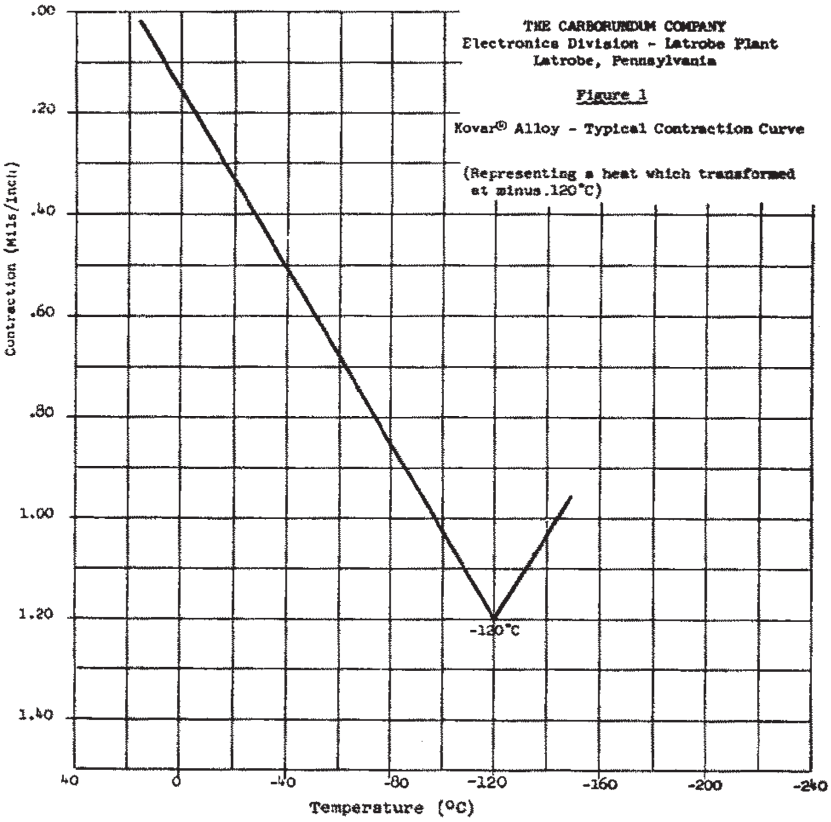
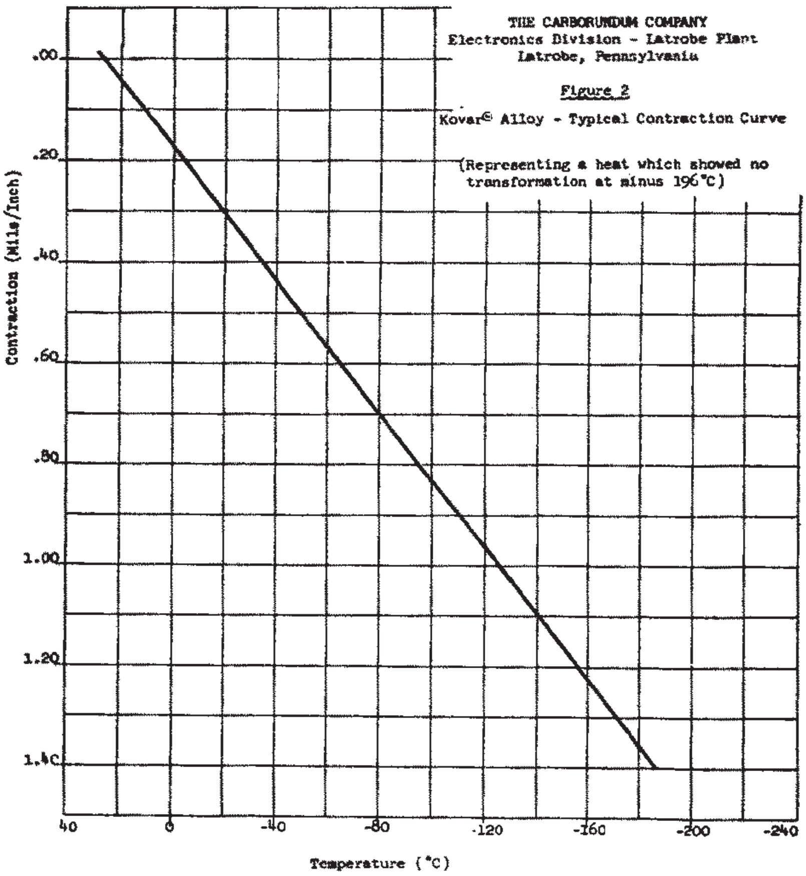

THE CARBORUNDUM COMPANY
Electronics Division - Latrobe Plant
Latrobe, Pennsylvania
Figure 1
Kovar® Alloy - Typical Contraction Curve
(Representing a heat which transformed at minus 120°C)
-120°C
Contraction (Mils/Inch)
.00
.20
.40
.60
.80
1.00
1.20
1.40
40
0
-40
-80
-120
-160
-200
-240
Temperature (°C)


THE CARBORUNDUM COMPANY
Electronics Division - Latrobe Plant
Latrobe, Pennsylvania
Figure 2
Kovar® Alloy - Typical Contraction Curve
(Representing a heat which showed no transformation at minus 196°C)
Contraction (Mils/Inch)
.00
.20
.40
.60
.80
1.00
1.20
1.40
40
0
-40
-80
-120
-160
-200
-240
Temperature (°C)