TECHNICAL DATA

METALLOGRAPHIC PROCEDURE FOR SAMPLE PREPARATION AND ETCHING OF KOVAR®

File Reference: 100EB1 — Sheet 1 of 1

Latrobe Plant — Latrobe, Pa.

REFRACTORIES DIVISION

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 disturbed 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.)

TECHNICAL DATA

BRAZING AND WELDING OF KOVAR® ALLOY

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

The most serious problem in regard to the brazing of KOVAR® is that of intergranular penetration. This is especially severe when the KOVAR is under stressed tension. In such cases it is extremely inadvisable to braze with alloys whose flow point is below 850° C, since intergranular penetration and subsequent leakage of the joint will be severe. Intergranular penetration will be disastrous to the joint if the joint will be subsequently reheated on glassing or baking operations, or if the joint is to be run hot and cold. Under these circumstances differential expansion between the penetrated solder grains and the adjacent KOVAR grains will split the KOVAR. However, although brazing of KOVAR under stressed tension is inadvisable as a general fact, considerably better joints will be had with brazing alloys melting above 850° C since the KOVAR will be stress relieved in being brought to the brazing temperature.

The thickness of the KOVAR may also be of importance, penetration being most critical the thinner the KOVAR. The reasons for these intergranular penetrations are not well known and it should not be presumed that the phenomena is due primarily to the silver content, but is more probably linked to the critical temperatures of the KOVAR treatment. This is indicated by the fact that pure silver, which melts and flows at 960° C. will give much less penetration than a solder such as B.T. which is only 72% silver, but melts at approximately 780° C. Since to achieve the low melting point desired by some solders and still maintain workability, it is necessary to include silver in the composition, there may be no more than a coincidence between the silver content of brazing alloys and intergranular penetration.

Copper plating of KOVAR prior to silver brazing may assist in preventing intergranular penetration of the silver solder. It is found that brazing KOVAR, not under stressed tension, with brazing alloys melting above 850° C, in a reasonably clean atmosphere, is a perfectly safe and simple procedure.

KOVAR is used in many applications that involve vacuum on one side of the joint. For such applications it is recommended that no brazing alloy is used which contains a high vapor pressure constituent, such as cadmium, zinc, lead, etc. The same is true of most ofthe fluxes now on the market. It is likely that one of the following will occur unless extreme care is used.

1. Vaporization of the high vapor pressure constituent onto some other portion of the device where it may be objectionable.

2. A leaky joint due to loss of one of the constituents of the brazing alloy used to make the joint.

3. Corrosion, due to improper removal of fluxes.

It is further recommended that brazing of KOVAR be conducted, if possible, in a reducing atmosphere, preferably hydrogen, in such a manner that the parts to be joined are heated rather uniformly to avoid a residual stressed condition.

Any operation not normally considered as a working operation will strain KOVAR sufficiently to make it advisable that the KOVAR be reannealed between this operation and the subsequent brazes. These operations include welding, riveting, etc., adjacent or upon the joint to be further brazed.

To summarize:

1. KOVAR should be annealed before brazing.

2. It is desirable if the joint is to be vacuum tight and dependable that the KOVAR portion of the joint should not be brazed under stressed tension. If it is necessary to do so the use of silver solders, especially those melting below 850° C., will make the operation critical. If this joint is to be further reheated the use of the above solders may be disastrous.

3. When brazing KOVAR it is advisable to maintain the brazing alloy above its flow point for as short a period as is possible, preferably only long enough to form a satisfactory joint.

4. Fluxes and high vapor pressure constituents in brazing alloys are undesirable for vacuum tight joints unless care is taken in brazing and cleaning and the joints operated at room temperature.

5. Welding and other operations upon annealed KOVAR should be followed by a second anneal before brazing same.

6. The solders on the attached list for vacuum tight joints are in the order in which their use is recommended on KOVAR with attention to the economics involved and the five points listed above. (A list of usable solders for non-vacuum joints is also given, without indicating preference.)

SILVER BRAZING OF KOVAR®

Precautions to be observed:

1. Brazing surface to be free of longitudinal scratches.
2. Anneal KOVAR parts before brazing.
3. Plate the brazing surface of KOVAR with copper or nickel.
4. Preferred design with KOVAR in compression rather than in tension. (For example: When joining KOVAR to copper it is preferable to have copper on outside of KOVAR, but if necessary to have copper on inside, allow sufficient clearance between parts.)
5. Preferably use a eutectic brazing alloy (such as Handy & Harman "BT" - 72% silver, 28% copper - melting and flow points 780° C.)
6. Brazing temperature to be applied uniformly to avoid thermal stressing. Hydrogen atmosphere furnace or resistance coil under Bell Jar.
7. Reduce temperature immediately after melting point of braze is reached.
8. Keep the re-heating of brazed joints to a minimum.

NOTE: The reason for most of the above precautions is the fact that KOVAR, in common with other nickel alloys, is subject to stress corrosion, which may lead to cracks. This phenomena does not occur when the brazing medium has a melting point above 850° C, at which temperature the KOVAR is stress relieved during the brazing operation.

LOW VAPOR PRESSURE BRAZING ALLOYS FOR VACUUM TIGHT JOINTS

(In Preferred Order)

	Melting Point °C	Flow Point °C		
(1)	1,082	1,082	Copper (OFHC)	Cu 100
	(888	901	18K Red #7, Handy & Harman	Au75, Cu20, Ag5
	(910	935	14K Red #6, Handy & Harman	Au58, Cu40, Ag2
(2)	(938	960	10K Red #6, Handy & Harman	Au42, Cu55, Ag3
	(1,063	1,063	24K Gold	Au100
(3)	960	1,025	(W) Patented Alloy	Ag5, Cu95
(4)	946	985	SN7, Handy & Harman	Ag7, Sn8, Cu85
(5)	960	960	Fine silver	Ag100
	(641	704	"Sil-fox" Handy & Harman (On copper plated KOVAR® only)	Ag15, Cu80, P5
(6)	(707	750	Phos-Copper (W) (On copper plated KOVAR only)	Cu93, P7
	(779	779	"BT" Handy & Harman	Ag72, Cu26
	(779	850	50-50	Ag50, Cu50

BRAZING ALLOYS FOR NON-VACUUM TIGHT JOINTS
(All Handy & Harman Designations)

COMMON SILVER SOLDERS

Name	COMPOSITION Silver	Copper	Zinc	Melting Point °F	Flow Point °F
ATT	20	45	30 (5% cadmium)	1430	1500
RT	60	25	15	1260	1325
EASY-FLO	50	15-1/2	16-1/2 (18% cadmium)	1160	1175
EASY-FLO #3	50	15-1/2	15-1/2 (16% cadmium) (3% nickel)	1195	1270

UN-COMMON SILVER SOLDERS

TE Special	5	58	37	1575	1600
TL	9	51	40	1510	1600
AT Special	20	45	35	1430	1500
NE	25	52-1/2	22-1/2	1500	1575
NT	30	38	32	1370	1410
SS	40	30	28 (2% nickel)	1240	1435
DT	40	36	24	1330	1445
DE	45	30	25	1250	1370
ET	50	28	22	1250	1340
ETX	50	34	16	1275	1425
RE-MN	65	28	(5% manganese) (2% nickel)	1385	1445
EASY	65	20	15	1280	1325
MEDIUM	70	20	10	1335	1390
BT	72	28	--	1435	1435
HARD	75	22	3	1365	1450
HARD #1	75	20	5	1350	1425
TR #1	75	--	25	1300	1345
IT	80	16	4	1360	1460

GOLD

Name	Gold	COMPOSITION Silver	Copper	Zinc	TEMPERATURE Melt °F	Melt °C	Flow °F	Flow °C
10K Easy	41.7	32	16.3	10.	1330	721	1360	738
14K Easy	58.3	11	10	11.7	1335	724	1365	740
19K White	80	12 Nickel		8	1555	846	1625	865
14K Yellow 245	58.30	24.78	16.78	.14	1500	815	1540	838
14K Yellow 165	58.30	16.50	25	.20	1475	801	1545	840
6K Enamelling (White)	25.	48.15	22.3	4.55	1360	738	1385	751
6K Easy (White)	25.	45.	19.7	10.3	1290	699	1325	781

TECHNICAL DATA

MACHINING OF KOVAR® ALLOY

File Reference: 100EB3 — Issue 3

Latrobe Plant — Latrobe, Pa.

REFRACTORIES DIVISION

Kovar® machines readily at slow speeds with high speed or tungsten carbide tools when properly lubricated.

Feed

Use same rules as normally applied to Monel "R" Metal (with carbide tools, satisfactory results were obtained at 155-225 S.F.M., .005" per revolution feed and depth of cut .010").

Further details on machining Monel "R" Metal are given in bulletin T-12 "Machining Nickel Alloys" of the International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

Lubricant

Lard oil or commercial coolant, such as "Socony-NC-704 (4 to 7% sulphur)" or Carbide & Carbon Company "UCON-660" or Fiske Refining Company "S-277 (sulphur free mineral oil)".

Tools

High speed material, such as "Rex-95".

Tungsten Carbide - such as Kennametal Grade K-6 or K-3H.

Tool Clearance

Side Clearance Angle	-	10° - 12°
Front Clearance Angle	-	8°
Back Rake Angle	-	12° - 14°
Side Rake Angle	-	12° - 14°

These angles are typical, but vary considerably by conditions of each individual job.

TECHNICAL DATA

CLEANING OF OXIDIZED KOVAR ALLOY

File Reference: 100EB4 Issue No. 2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

1. VAPOR DECREASE

   (a) Trichlorethylene or equivalent (if parts are greasy)

2. PICKLE

   (a) Solution Composition:

Concentrated Hydrohloric Acid	100%
Preferably with Inhibitor (such as Rodine #50, made by American Chemical Paint Co., Ambler, Pa.)	Plus 1%

   (b) Temperature 80 - 85° C

   (c) Time

Light Scale	1/2 - 1 min. immer-
Heavy Scale	1 - 5 " sion

3. RINSE

(a) Running Hot Water	30 Seconds
(b) Cold Concentrated Hydrochloric Acid	5 - 10 Seconds
(c) Running Cold Water	30 Seconds

4. BRIGHT DIP (Omit steps 3 (b) and 3 (c))

   (a) Solution Composition

Acetic Acid	750 cc
Nitric Acid	250 cc
Hydrochloric Acid	15 cc

   (b) Temperature Room

   (c) Time 3 - 10 sec. immersion

5. RINSE

   (a) Running Cold Water

   NOTE: If the degree of brilliance is not achieved in the first immersion, bright dipping may be repeated.

   CAUTION: The action of the bright dip on Kovar Alloy is very rapid. Hence, only cleaned Kovar Alloy should be bright dipped to minimize immersion time in brightening solution.

   (b) Alcohol
   (c) Air Dry

TECHNICAL DATA

THERMAL CONDUCTIVITY OF KOVAR ALLOY

File Reference: 100EB5 Issue No.2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

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 conductivity, 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 cm^2 per °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.)

TECHNICAL DATA

KOVAR-GLASS SEALING PROCEDURE
(For Electron Tubes)

File Reference: 100EB6 Issue 2 Sheet 1

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

The recommendations given in the bulletin refer particularly to electron tube construction. For less critical applications, the procedure may be altered to meet less exacting conditions.

I. Preparation of Metal Surface

A. On edge type seals, the edge should be rounded by metal removal with a radius equal to approximately one-half of the metal thickness.

Machine lubricants to be non-corrosive mineral oil base capable of being completely removed by trichlorethylene degreaser.

B. Polish sealing surface with 180-Grit Aluminum Oxide (ALOXITE) abrasive cloth, followed by 260-Grit to remove all scratches, tool marks, etc.

1. Emery cloth and other abrasives containing carbides must be avoided.

2. Centerless ground rod requires no additional polishing.

C. On Butt Type Seals, instead of cloth polishing, it is preferable to have a matte finish, as resulting from sand blasting using pure alumina (silica sand is to be avoided).

The metal surface which will be enveloped by glass should be clean and free from longitudinal die marks, scratches, and similar imperfections. Circular marks put in by grinding or polishing are not considered objectionable.

II. Preparation of Glass (Typical Sealing Glass for Kovar - Corning 705-2)

A. Remove dust by wiping with lint-free cloth.

B. Rinse in 10% (by volume) Hydrofluoric Acid Solution (with wetting agent)

C. Rinse in running tap water.

D. Rinse in distilled water.

E. Dip in Menthanol and hot air dry.

III. Processing Kovar Alloy Prior to Glass Sealing

A. Vapor degrease in Trichlorethylene.

B. Immerse for one to three minutes in concentrated hydrochloric acid without inhibitor heated to about 80°C.

C. Rinse thoroughly in cold running water for five minutes, followed by immersion in distilled water.

D. Dip in Menthanol and dry in hot air blast.

E. Furnace heat treat in wet hydrogen atmosphere.

1. Hydrogen to be saturated by passing thru water - bubbling bottle at room temperature.

2. 1 - Hour at 900°C. or 30 minutes at 1000° C.

F. Store in lint-free containers (Bell Jar or wrap in Polyethylene bags)

G. Precautions:

1. Sealing surface of cleaned parts not to be touched by bare hands.

2. Processing of metal parts to be done as soon as practical before glass sealing.

IV. Glass Sealing

A. Equipment:

1. Burner preferably using gas-oxygen flame (gas and air or hydrogen and air combinations may be used either of which are harder to adjust to required hard-sharp oxidizing flame than the preferred gas-oxygen flame).

2. Glass lathe.

B. Heat metal and glass parts to approximately 850°C. (dull red heat) in air to develop oxydized surface and bring parts together by pressure.

Before glassing the oxide should be just thick enough to obscure all metallic reflection.

C. Glass to be worked so that the meeting of the edge with the Kovar approaches a 90° angle (feather-edging of the glass and glass having a re-entrant angle both result in mechanically weak seals.)

D. Flame anneal seal.

E. Furnace program anneal for large seals.

1. Advance to annealing temperature for 30 minutes.

2. Annealing temperature to 50°C. below strain point at approximately 1°C. per minute.

3. Strain point to room temperature at approximately 10°C. per minute. (Note:- Small seals may be flame annealed by smoky flame instead of program annealed).

For high quantity production, the glass sealing operation may be done by automatic stem machine, induction heating or neutral atmosphere furnace. Pre-oxidized metal parts are generally used on the latter two methods. A typical cycle for pre-oxidation is heating for three minutes at 900°C. in an electric furnace with air atmosphere. The cycle must be varied according to furnace heating capacity and humidity conditions.

V. Inspection

A. Seal to have desired stress condition as determined by polariscope viewing or by other stress analysis method.

B. The color of the seal shall be grayish in color (or mouse brown for certain glasses).

C. A shiny appearance indicates insufficient oxide and black surface indicates excessive oxide.

D. Examination under 10 to 15 Power Magnification shall show freedom from a string or excessively large group of bubbles entrapped in the glass.

E. Transformation Test: - Wrap seal in tissue paper and immerse in dry ice and Acetone mixture (-80°C.) for 30 minutes.

1. Adequate paper wrapping is required to take care of difference in thermal conductivities of metal and glass.

2. After the sample is allowed to cool to room temperature no cracks in the glass should be visible under 7 to 10-Power Magnification.

VI. Oxide Removal

A. Vapor degrease in Trichlorethylene (if parts are greasy).

B. Pickle.

1. 100% Hydrochloric Acid

2. Heat to 80 to 85°C.

3. Immerse parts for one minute (longer for more heavily oxydized seals).

C. Rinse.

1. Running hot water - 30 seconds.

2. Cold concentrated HCL - 5 to 10 seconds.

3. Running cold water - 3 minutes.

4. Rinse in distilled water.

5. Dip in Acetone and air dry.

TECHNICAL DATA

RECENT DEVELOPMENTS IN CLEANING KOVAR ALLOY

File Reference: 100EB7 Issue No.2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

Considerable work has been done at Bell Telephone Laboratories, Murray Hill, New Jersey, on a novel method for cleaning all parts for electron tube applications. This Hydrogen Peroxide process is especially applicable for final cleaning of Kovar alloy parts just prior to sealing to glass, as follows:

1. Materials

   (a) C.P. 30% Hydrogen Peroxide (Such as Merck "Super Oxyl" without stabilizer).

   (b) De-ionized water preferred although distilled water may be used.

2. Procedure

   (a) Immerse parts in de-ionized water, bring toboil, adding enough peroxide to make a 5% solution.

   (b) Boil 20 - 30 minutes.

   (c) Overflow rinse with tap water.

   (d) Rinse in de-ionized water.

   (e) Dry in air furnace.

   (f) Store in glass containers which have been previously cleaned by the Hydrogen Peroxide method described above.

The Hydrogen Peroxide procedure has been found to be effective in removing all traces of surface contamination including pick-up of organic materials from the atmosphere. Theefficacy of this cleaning may be determined by a Wetability test.

A further refinement in eliminating organic surface contaminants in the preliminary cleaning of Kovar Alloy is to heat the Kovar Alloy parts to 400° C in an air atmosphere just prior to hydrogen firing.

NOTE: The cleaning methods described above are in addition to the standard procedure outlined in Engineering Bulletin 100EB6.

TECHNICAL DATA

KOVAR® ALLOY WEIGHT CONVERSION FACTORS

File Reference: 100EB-8 Issue No. 3

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

GENERAL

DENSITY OF KOVAR ALLOY IS .302 LBS PER CUBIC INCH. WHEN USING WEIGHT TABLES FOR STEEL SHAPES MULTIPLY BY FACTOR OF 1.065 TO OBTAIN EQUIVALENT WEIGHT IN KOVAR ALLOY.
EXAMPLE: FROM WEIGHT TABLE FOR STEEL ROD 1" DIA. WEIGHT 2.670 LBS/FT TIMES 1.065 IS 2.84 LBS/FT FOR KOVAR ALLOY.

KOVAR® ALLOY STRIP

STANDARD STOCK SIZES THICKNESS (INCHES)	WIDTH (INCHES)	LBS/FT (1) FOR STANDARD WIDTH	LBS/FT (2) FOR SPECIAL 1" WIDTH
.005	6-1/2	.117	.018
.010	6-1/2	.234	.036
.015	6-1/2	.355	.054
.020	6-1/2	.468	.072
.030	13	1.40	.108
.040	13	1.87	.144
.050	13	2.33	.179
.060	13	2.80	.216
.100	13	4.67	.358
.125	13	5.85	.450

NOTE: TO FIND THE WEIGHT OF NON-STANDARD WIDTHS MULTIPLY THE NON-STANDARD WIDTH BY THE WEIGHT OF 1" WIDTH AS SHOWN IN COLUMN (2) ABOVE.
EXAMPLE: TO FIND THE WEIGHT OF .010 x 3/4" (.750)
.036 x .750 IS .027 LBS/FT.

KOVAR® ALLOY SEAMLESS TUBING

FORMULA: $(O.D^2$ MINUS $I.D^2)$ TIMES 2.84 IS WEIGHT IN LBS/FT.
EXAMPLE: TO FIND THE WEIGHT OF ONE FOOT TUBING 1" O.D. x .050" WALL (.90 NOMINAL I.D.)
(1 - .81) TIMES 2.84 IS .540 LBS/FT.

NOTE: KOVAR TUBING IS SOLD AND MEASURED BY THE FOOT. THE CONVERSION FACTOR OBTAINED BY THE ABOVE FORMULA DOES NOT TAKE TOLERANCES INTO CONSIDERATION AND IS ONLY AN APPROXIMATE FIGURE.

KOVAR® ALLOY ROD & WIRE

FORMULA: WEIGHT PER FOOT IS 2.84 TIMES DIAMETER SQUARED.
EXAMPLE: TO FIND WEIGHT OF 2-1/4" DIAMETER ROD: 2.84 TIMES $(2.250)^2$ IS 14.3 LBS PER FOOT.

ROD

DIAMETER (INCHES)	LBS/FT	DIAMETER (INCHES)	LBS/FT
.030	.0026	.500	.710
.035	.0035	.625	1.11
.040	.0045	.750	1.60
.050	.007	1.000	2.84
.060	.010	1.125	3.6
.070	.0138	1.250	4.5
.080	.018	1.375	5.4
.0938	.025	1.500	6.4
.100	.028	1.625	7.5
.125	.045	1.750	8.7
.156	.069	2.000	11.4
.1875	.100	2.125	12.9
.250	.178	2.500	17.7
.3125	.278	3.000	25.5
.375	.400		

WIRE

DIAMETER (INCHES)	FT/LB
.005	14300
.010	3500
.013	2100
.015	1500
.018	1080
.020	900
.025	580
.030	400
.035	300
.040	225
.045	175
.050	145
.060	100
.080	55

TECHNICAL DATA

PROPERTIES OF KOVAR "A" ALLOY

File Reference: 100 EB-9 Issue 2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

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 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 Linear 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 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

TECHNICAL DATA

PROPERTIES OF KOVAR "A" ALLOY

File Reference: 100EB-9 Issue 2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

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

TECHNICAL DATA

PROPERTIES OF KOVAR "A" ALLOY

File Reference: 100EB-9 Issue 2

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION

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.

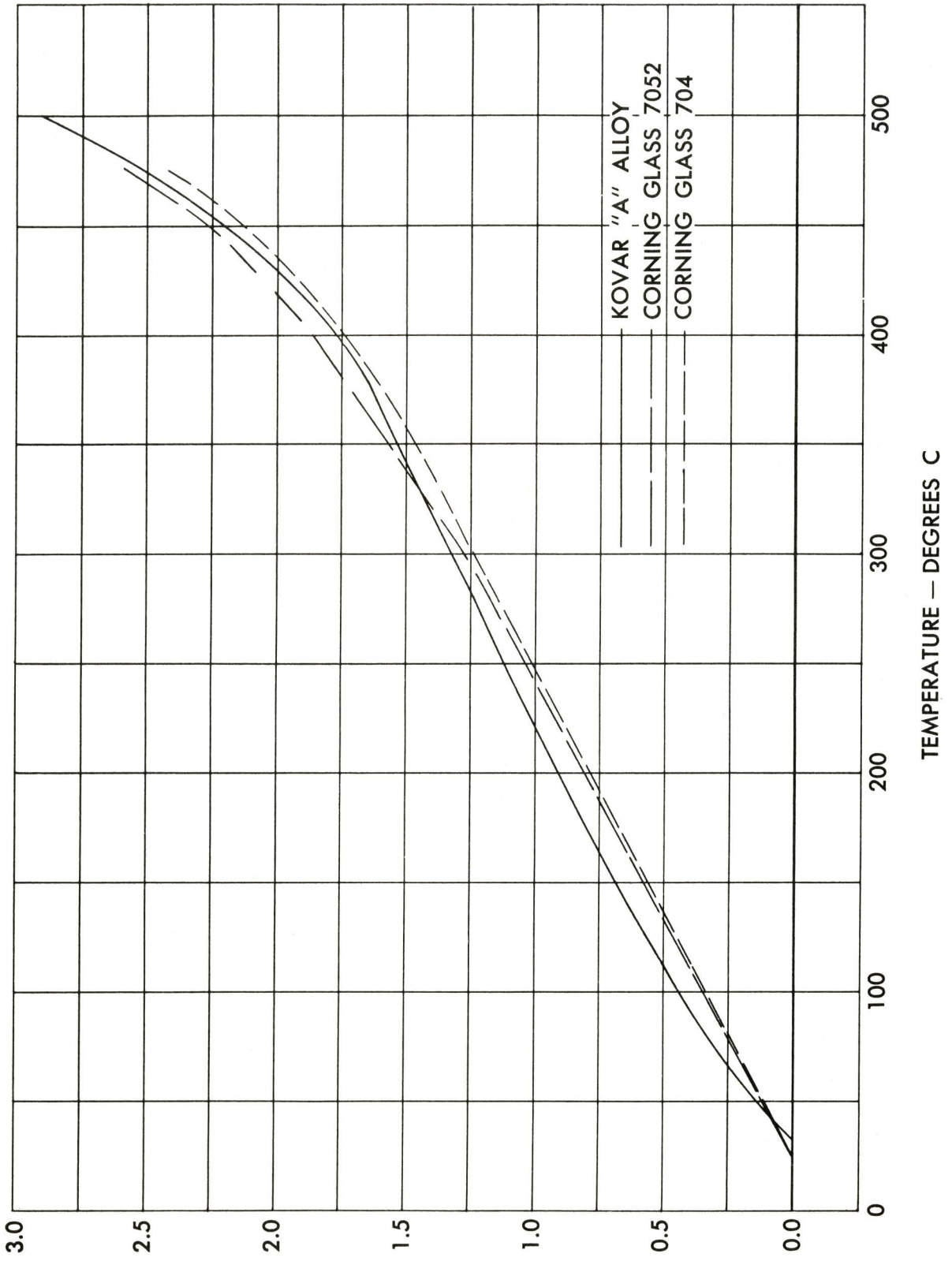
TECHNICAL DATA

Properties of KOVAR A Alloy

File Reference: 100 EB-9 Issue No. 1

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION



THE CARBORUNDUM COMPANY

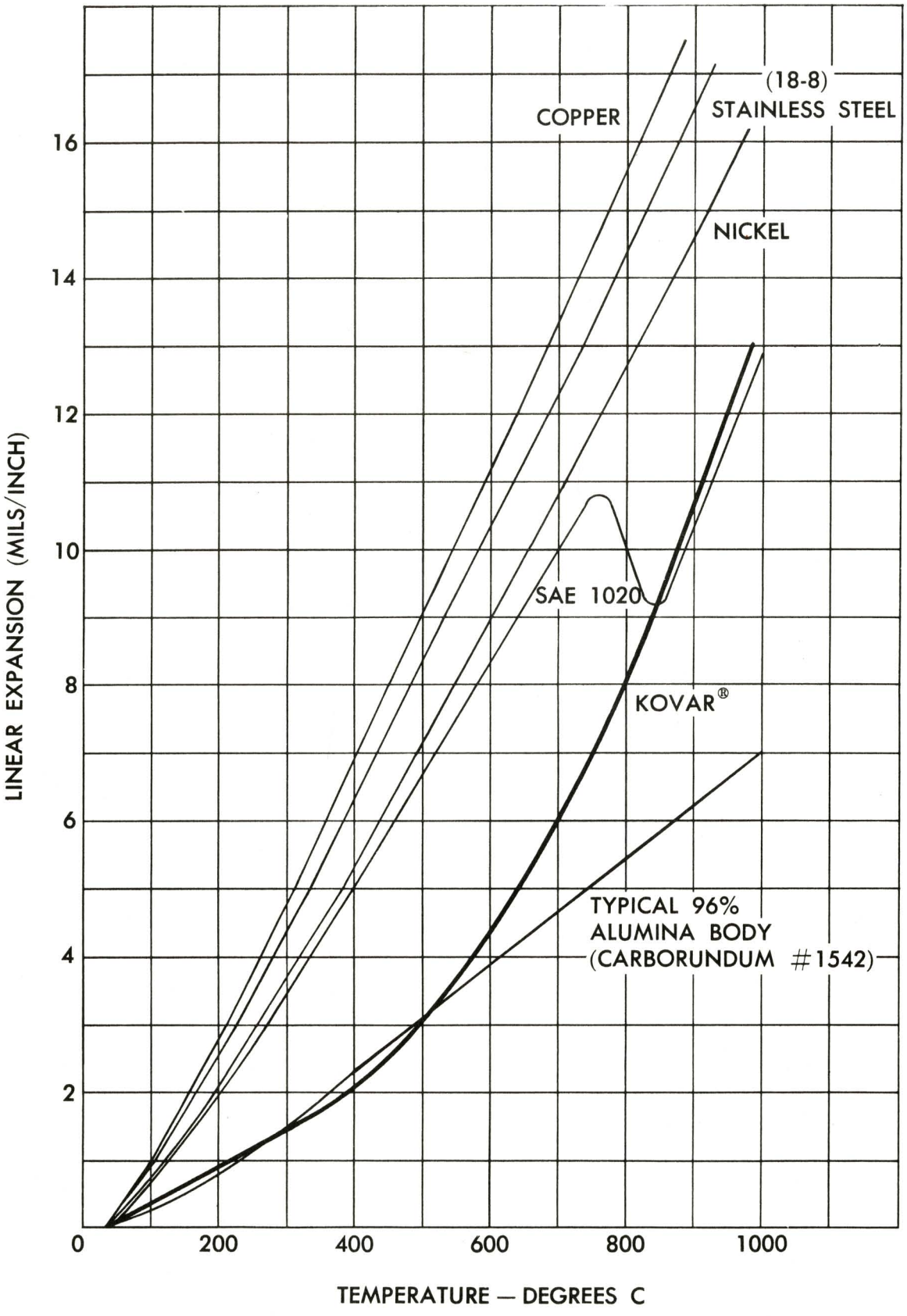
TECHNICAL DATA

Properties of KOVAR A Alloy

File Reference: 100 EB-9 Issue No. 1

Latrobe Plant Latrobe, Pa.

REFRACTORIES DIVISION



TECHNICAL DATA

KOVAR® ALLOY WIRE SPOOL CHART

File Reference: 100EB-10 — Issue No. 1

Latrobe Plant — Latrobe, Pa.

REFRACTORIES DIVISION

Spool No.	Price	Capacity	Head Dia.	Barrel Dia.	Traverse	Overall Length	Bore	Tare wt.	Remarks
#2 Tin	$ .25	1#	3"	1-3/4"	3"	3-1/4"	5/8"	.29	Non-returnable
#3 Yellow Plastic	.40	5#	4-1/2"	2"	3"	4"	5/8"	.50	Annealed (Soft) Wire only
453-C Metal	1.50	5#	4-1/2"	2-3/4"	3"	3-1/4"	5/8"	1.70	
4AMB Wood Metal Bound	1.00	10#	6"	2-1/2"	3"	4"	5/8"	1.25	
46M Metal	1.50	10#	4"	1-3/4"	6"	6-3/16"	5/8"	1.28	Special Order Only

Note 1: Spools are charged at cost and full credit will be given upon return to us, F. O. B. Latrobe, Pa.