BROOKHAVEN NATIONAL LABORATORY
Brookhaven Science Associates
Upton, New York 11973

SPECIFICATION FOR:

Heat Treatment for Vanadium Permendur

QA CATEGORY A-3		
OUTSTANDING ECN's		

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
UPTON, N.Y.
Form 1803

Heat Treatment for Vanadium Permendur

	SLS-07.146-001	-1	A
JOB NUMBER	DRAWING NUMBER	SIZE	REV

REVISION CONTROL SHEET

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1.0 SCOPE

This specification describes the heat treatment process for vanadium permendur. Vanadium permendur is the generic name for the iron-cobalt-vanadium alloy which has magnetic properties (high magnetic saturation, high magnetic permeability, low D.C. coercive force) which make it attractive as a magnetic pole material. The alloy is comprised of about 49% Fe, 49% Co and 2% V. (Small quantities of Mn, Si, C and other materials may be added, depending on the specific manufacturer, and these variants may have differing trade names). The 2% Vanadium is added to the material to improve machinability. The bulk material should be purchased in the annealed state and heat treated after final machining as described herein to achieve peak magnetic properties.

2.0 REFERENCES

ASTM A-801-T1, Vanadium Permendur Material Spec.

Hyperco 50A, Scientific Alloys Trade Name, Specification for Heat Treatment

Heat Treatment For Magnetic Properties, Specification for Vanadium Permendur, Lawrence Berkeley Laboratory specification dated 5/15/1995.

3.0 HEAT TREATMENT FOR MAGNETIC PROPERTIES

The following procedure is required after machining of vanadium permendur parts to restore optimum magnetic properties:

A. IMPORTANT!: Final heat treatment of all vanadium permendur parts in a common assembly is to be performed in one batch.

B. Clean all parts to remove surface contamination.

C. Anneal for 4 hours at 1600° F (871° C) in a dry hydrogen (at 1 atm. pressure) or vacuum furnace set at a pressure less than or equal to $1x10^4$ torr. Slow cool at a rate not to exceed 180°/hr (100° C/hr). Control cool down rate from 1600°F (875° C) down to 750° F (400° C). Below 750° F (400° C) any cooling rate may be used. Position temperature sensors to ensure that all parts reach maximum temperature for a full 4 hours.

D. Test a stainless steel coupon through the entire heat cycle prior to heat treating the vanadium permendur poles. Coupon should be clear of oxides and discoloration when removed from retort.

E. Support parts in furnace to minimize distortions during heat treating process.

F. After heat treatment, surfaces of part must be clean and free of oxides, and/or discoloration. Do not use powders or drying agents which are contaminated with water during heat treatment, since this may result in an oxide coating on the part(s).

G. Certification of heat treatment is required. This certification must include temperature/time graphs. NOTE: Temperature must not exceed 1600° F (871°C) during process. Operator must verify that the proper temperature plateau has been reached, and that no over temperature shoot has occurred. Operator must initial and date time/temperature graph at this time.

H. If dry hydrogen atmosphere is used, dew point of gas entering retort must not exceed -60° F (-51° C). The exiting dew point must be dryer than -40° F (-40° C). Dew point measurement to be included with time/temperature certification.

I. IMPORTANT! Care in handling, storing and packaging must be exercised at all times to protect parts from any surface damage.

4.0 SOURCES OF SUPPLY

The following is a limited list of suppliers for vanadium permendur.

Vasco-Pacific
707 West Olympic Blvd.
Montebello, CA 90640
(213) 723-5331

Telcon Metals Limited
Napier Way
Crawley
West Sussex, England
44-293-528800

Scientific Alloys
P.O. Box 523
Westerly, RI 02891
(401) 596-4947

Surepure Chemicals, Inc.
23T Woodbine Rd.
Florham Park, NJ 07932

(201) 377-4081

Dexter Magnetics
48460 Kato Road
Fremont, CA 94538-7337
(510) 656-5700

Carpenter Technology
P.O. Box 14662
Reading, PA 19612-4662
(215) 208-2802

Metalimphy
2975 Advance Lane
Colmar, PA 18915
(215) 822-1348

Vacuumschmelze
c/o Siemens Components, Inc.
186 Wood Avenue South
Iselin, NJ 08830
(210) 494-3530

APPENDIX

Attached are some physical, magnetic, heat treatment, and machinability properties, courtesy of Scientific Alloys, Inc. for Hyperco 50A, which may be considered typical for vanadium permendur products.

CARPENTER TECHNOLOGY CORPORATION
CARPENTER STEEL DIVISION
CRTECH®

Hiperco® Alloy 50A

Type Analysis

Carbon	0.004%	Cobalt	48.75%
Manganese	0.05%	Vanadium	2.00%
Silicon	0.05%	Iron	Balance

Description

Hiperco® alloy 50A is an iron-cobalt-vanadium soft magnetic alloy possessing high magnetic saturation (24 kilogauss), high D.C. maximum permeability, low D.C. coercive force, and low A.C. core loss. This alloy exhibits magnetic properties superior to those of other commercial iron-cobalt soft magnetic alloys.

In addition, Carpenter produces Hiperco alloy 50 which has nearly the same nominal analysis as Hiperco alloy 50A, but contains small additions of niobium and carbon for grain refinement to achieve higher mechanical strengths with only a slight sacrifice in magnetic properties. Hiperco alloy 50's higher strength is necessary for rotating component laminations subject to stress from high rotational speeds. Hiperco alloy 50 has been used in strip form primarily for aircraft generators and motors. Contact Carpenter for technical data.

Applications

Hiperco alloy 50A has been used primarily for magnetic cores in electrical equipment requiring high permeability at high magnetic flux densities. It has also been used in tape cores where lowest A.C. losses and high permeability at high inductions are desired.

Physical Properties

Specific gravity	8.12	Modulus of elasticity X 10⁶ psi	30
Density		Saturation magnetostriction	
lb/cu in	0.293	change in unit length X10⁶	60
kg/cu m	8120	Thermal conductivity	
Electrical resistivity		watts-cm/cm²°C	0.298
ohms cm/f	241		
microhm-mm	400		
Curie temperature			
°F	1724		
°C	940		

Mean coefficient of thermal expansion

Temperature		Coefficient	
77°F to	25°C to	10⁻⁶/°F	10⁻⁶/°C
392	200	5.3	9.5
752	400	5.6	10.1
1112	600	5.8	10.5
1472	800	6.3	11.3

12-92/4.5M

Heat Treatment

Standard Treatment
Anneal parts at 1575/1600°F (857/871°C) for 2 to 4 hours in dry hydrogen or vacuum and cool at 150/350°F (83/194°C) per hour until 600°F (316°C) is reached, after which any cooling rate can be employed.

It is important to avoid any contamination of the finished fabricated parts during the heat treatment. All parts must be cleaned thoroughly to remove any surface contaminants prior to being placed in an air-tight retort.

A dry hydrogen atmosphere or a high vacuum is recommended to minimize oxide contamination of the parts during annealing. When hydrogen is employed, the entry dew point should be dryer than -60°F (-51°C) and the exit dew point dryer than about -40°F (-40°C) when the inside retort temperature is above 900°F (482°C).

Optional Treatments
For Centerless Ground Bars ≤ 1.250" (31.75 mm) Diameter—
This duplex practice is only recommended for centerless ground bars in the size range given. Larger centerless ground bars, shapes, or hot rolled bars may be subject to cracking if quenched in this manner.

This is a two-step treatment where the first step conditions the material for best machinability while the second develops optimum magnetic properties.

Preheat treat 2 to 3 foot lengths at 1850°F (1010°C) for about 30 minutes in air or protective atmosphere and quench bars in cold agitated water with their long axes in the vertical position. This preheat treatment develops a coarse acicular martensitic type structure which imparts ductility to the material and improves machining of the finish part.

The second part of the duplex treatment involves the employment of the standard treatment as described earlier. At no time should the temperature of the second treatment exceed 1600°F (871°C) because of the formation of a nonmagnetic austenitic phase which transforms upon cooling, thereby degrading magnetic properties due to transformation stresses.

For Products Produced from Any Size Bar—
This practice can be applied to all parts produced from bar products, regardless of their size since no rapid quench practices are required. It provides improved capability magnetic properties on especially large cross sections compared to those of the standard heat treatment. Note, however, it is a lengthy process and, therefore, more expensive.

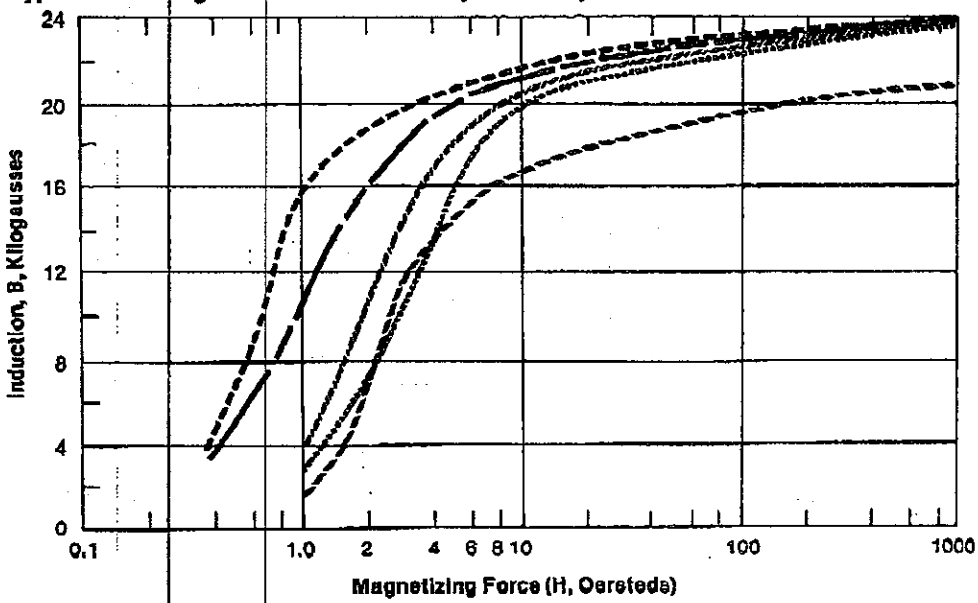
Heat the finish machined part in dry hydrogen or high vacuum to 1700°F (927°C) (heating rate is not critical) and hold at 1700°F (927°C) for three to four hours. Cool at 20°F (11°C) maximum per hour to 1350°F (732°C), then cool to 950°F (510°C) at 200°F (111°C) per hour. Cool at any rate thereafter.

Magnetic Properties

Typical D.C. Magnetic Properties—Hiperco Alloy 50A
After heat treatment indicated.

Magnetic Properties Induction, (B) at Applied Field (H) Oersteds	Laminations or Tape Cores* Made from Strip 1600°F (871°C)	Standard Treatment of Bar 1600°F (871°C)	Option 1 Duplex Treatment for Parts Made from 1.25" Rd. + C.D. Bar 1850°F (1010°C) W.Q. Plus 1600°F (871°C)	Option 2 Slow Cool Treatment for Any Size Part or Bar 1700°F (927°C) Plus Controlled Slow Cool
B @ H = 2 Oe	15.5 Kg	10.0 Kg	16.0 Kg	11.0 Kg
B @ H = 4 Oe	18.6 Kg	15.5 Kg	19.0 Kg	17.5 Kg
B @ H = 6 Oe	20.0 Kg	18.0 Kg	20.2 Kg	19.0 Kg
B @ H = 10 Oe	21.0 Kg	20.0 Kg	21.0 Kg	20.0 Kg
B @ H = 50 Oe	22.7 Kg	22.5 Kg	22.7 Kg	22.5 Kg
B @ H = 100 Oe	22.9 Kg	22.8 Kg	22.8 Kg	22.8 Kg
B @ H = 200 Oe	23.5 Kg	23.0 Kg	23.0 Kg	23.0 Kg
H_c from H = 200 Oe	0.4 Oe	1.9 Oe	0.6 Oe	1.0 Oe

Typical D.C. Magnetization Curves—Hiperco Alloy 50A vs. Electrical Iron



- Hiperco alloy 50A strip, .035" (.89 mm) thick, 1625°F (871°C), 2 hr., dry H_2.
- Hiperco alloy 50A bar, 1875°F (1010°C), water quenched plus 1625°F (871°C), 2 hr., dry H_2.
- Hiperco alloy 50A bar, 1625°F (871°C), 2 hr., dry H_2.
- Hiperco alloy 50A bar, 1533°F (820°C), 2 hr., dry H_2.
- Electrical Iron bar, 1550°F (843°C), 4 hr., wet H_2, FC.

Workability

Machinability

The following charts include typical machining parameters used to machine Hiperco alloy 50A. The data listed should be used as a guide for initial machine setup only.

	High Speed Tools*				
TURNING AND FORMING TOOL WIDTH		Cut-Off Tool	1/16"	SFM	25
				FEED	.001
			1/8"	SFM	25
				FEED	.002
			1/4"	SFM	25
				FEED	.003
		Form Tool	1/2"	SFM	25
				FEED	.004
			1"	SFM	25
				FEED	.0025
			1-1/2"	SFM	25
				FEED	.002
DRILLING		Drill Dia.	3/8"	SFM	30
				FEED	.005
			3/4"	SFM	30
				FEED	.010
REAMING			Under 1/2"	SFM	65
				FEED	.0050
			Over 1/2"	SFM	65
				FEED	.010
THREADING		T.P.I.	3-7½	SFM	8
			8-15	SFM	10
			Over 16	SFM	15
TAPPING		T.P.I.	3-7½	SFM	6
			8-15	SFM	7
			16-24	SFM	11
			Over 25	SFM	15
MILLING				SFM	20-35
				FEED	.001-.005
BROACHING				SFM	8-15
				FEED	.002
TURNING— SINGLE POINT AND BOX TOOLS		High Speed Tools		SFM	25-30
				FEED	.003-.010
		Carbide Tools		SFM	70-90
				FEED	.020-.027

*When using carbide tools, surface speed feet/minute (sfm) can be increased between 2 and 3 times over the high speed suggestions. Feeds can be increased between 50 and 100%.

Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.