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Measurements of Materials for SIS Mixer Magnetic Circuits

G. A. Ediss and K. Crady
National Radio Astronomy Observatory
Charlottesville, VA 22903

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Abstract

Measurements have been made of various magnetic materials in order to improve the flux density at the SIS junction positions in the mixer. The materials measured are Hiperco 50A, HyMu 80, Consumet iron and Magnet iron. Magnet iron is recommended for unannealed use. Consumet is recommended for annealed use. Hiperco 50A can be used annealed if large hysteresis can be accepted. For highest flux density for lowest drive current, annealed Consumet should be used.

Measurements

In EDTN 190 [1], suggestions were made to increase the flux density at the junctions. These suggestions included increasing the diameter of the coil core (by a factor of 2), increasing the size of the cross arms at the joint with the core and tapering down to the size of the pole pieces, and using magnetic screws. Figure 1 shows the modified circuit which was used for the following measurements.

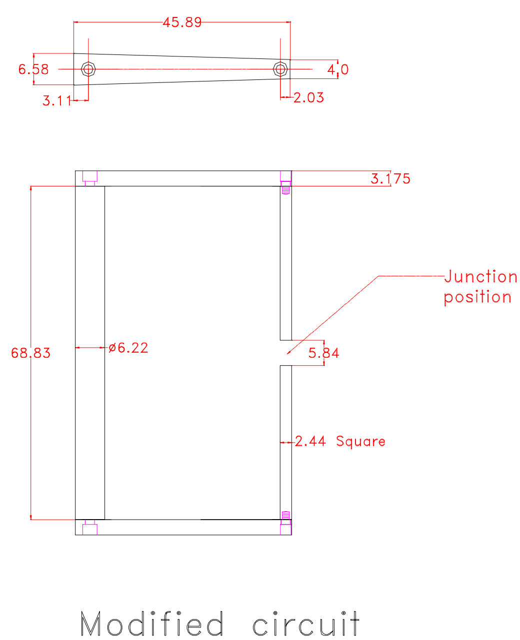

Figure 1. Dimensions in mm.

The measurements are made by driving the maximum current through the coil and then decreasing the current to zero, increasing in the opposite direction to maximum, then reducing to zero again and then increasing to maximum in the original direction. All curves in this memo are taken in this manner, and the initial rise to maximum current is not shown for clarity. The materials tested are given in Table 1 [2]. Table 2 gives other names for equivalent materials.

Table 1. Material Composition

Material	Composition %[1]	μinitial[2]	μmax[3]	Bsat (T)[4]
Hiperco 50A	49 Co, 48.8 Fe, 2.02 V, 0.005 C	800	4500	2.4
HyMu 80	80 Ni, 14.6 Fe, 4.53 Mo, 0.54 Mn, 0.006 C	35000	250000	0.8
Consumet iron	99.9 Fe, 0.001 C	200	5000	2.15
Magnet iron	99.45 Fe, 0.28 Mn, 0.02 C	250	5000	1.75
Hiperco 27 [5]	71 Fe, 27 Co, 0.01 C	-	2800	2.36

1) Rest - others (*i.e.*, Si, P, S, Cr, Cu, Al, Ti, etc.)
2) μinitial - initial permeability
3) μmax - maximum permeability
4) Bsat - saturation field (in Tesla = 10k Gauss)
5) This material was used in [1] and given for reference.

Table 2. Equivalent Materials
Materials in the same column have similar composition.

Hiperco 50A	HyMu 80	Consumet core iron	Magnet iron
Permendur 2V	Permalloy 80		Armco iron
Vanadium Permendur	Mu metal		ASTM-A-848 Alloy 1[1]
Vacoflux 50	4-79 Permalloy		
Vacodur 50	Superperm 80		
ASTM-A-801 Alloy 1	ASTM-753 Alloy 4		
	Cryoperm 10 (at 4 K)		

1) ASTM - American Society for Testing and Materials, online at http://www.astm.org/

Figures 2-5 give the measured flux density versus coil current for the four materials, unannealed.

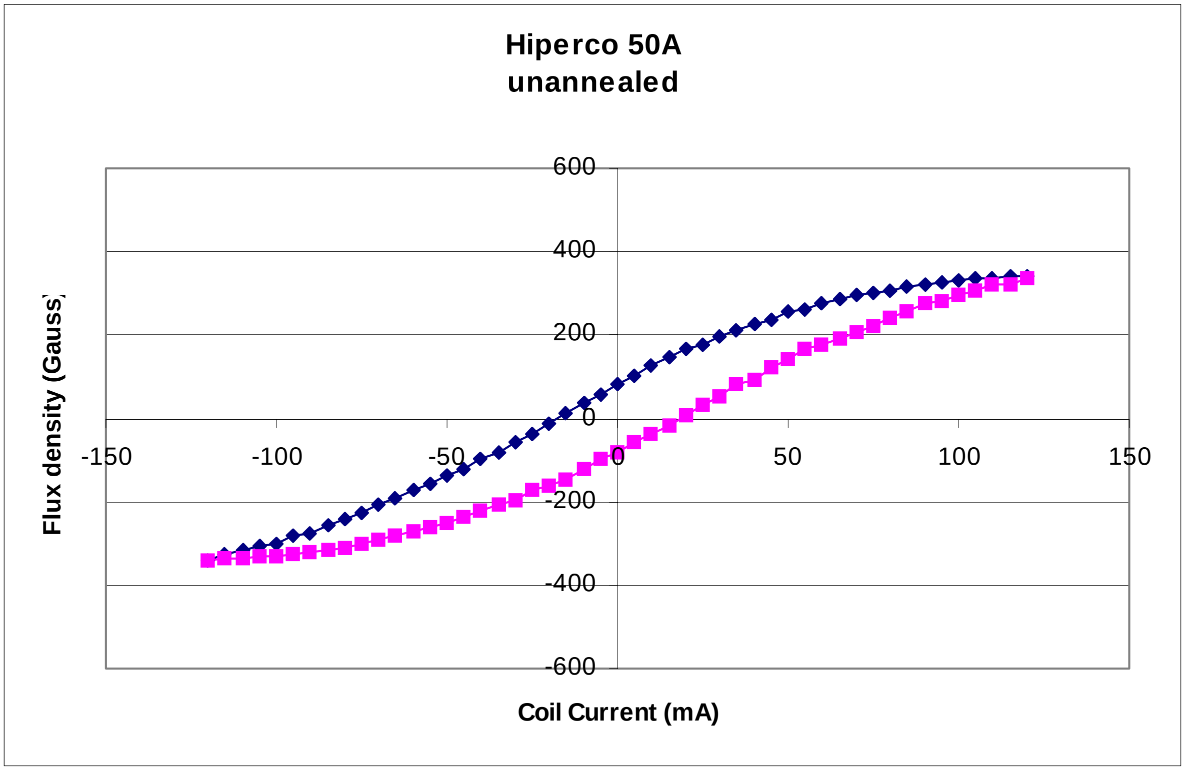

Figure 2

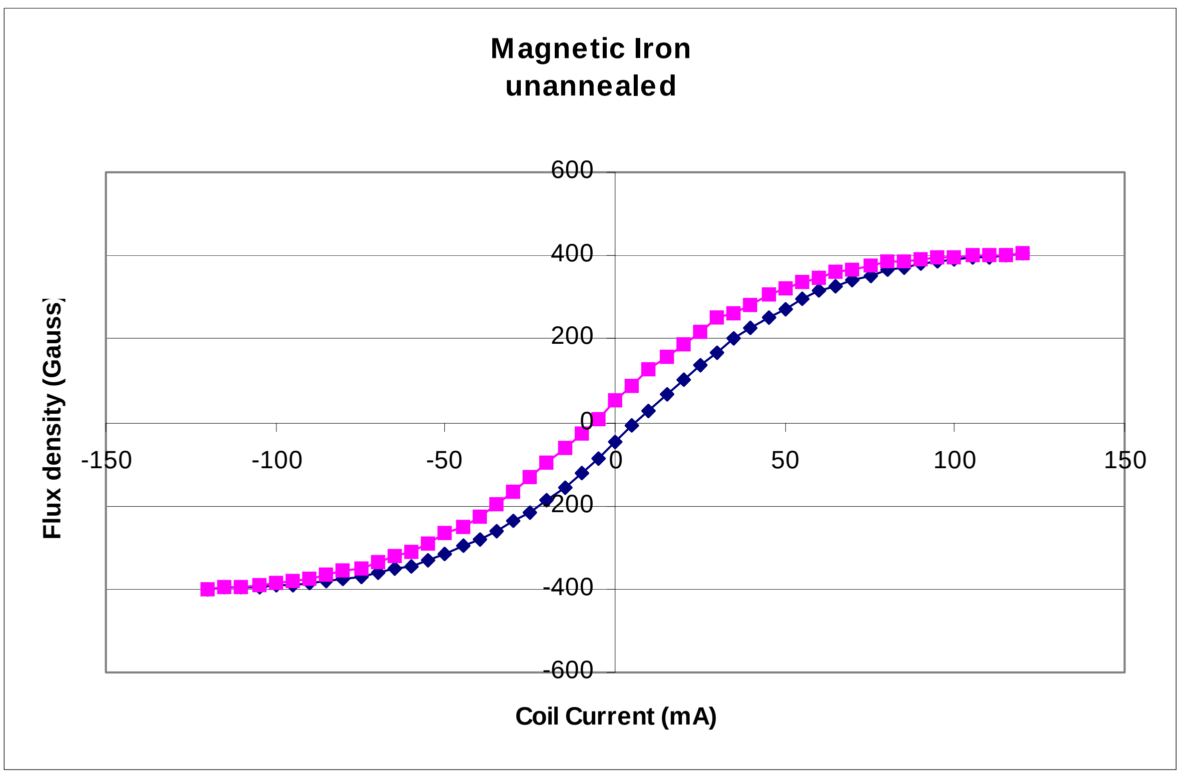

Figure 3

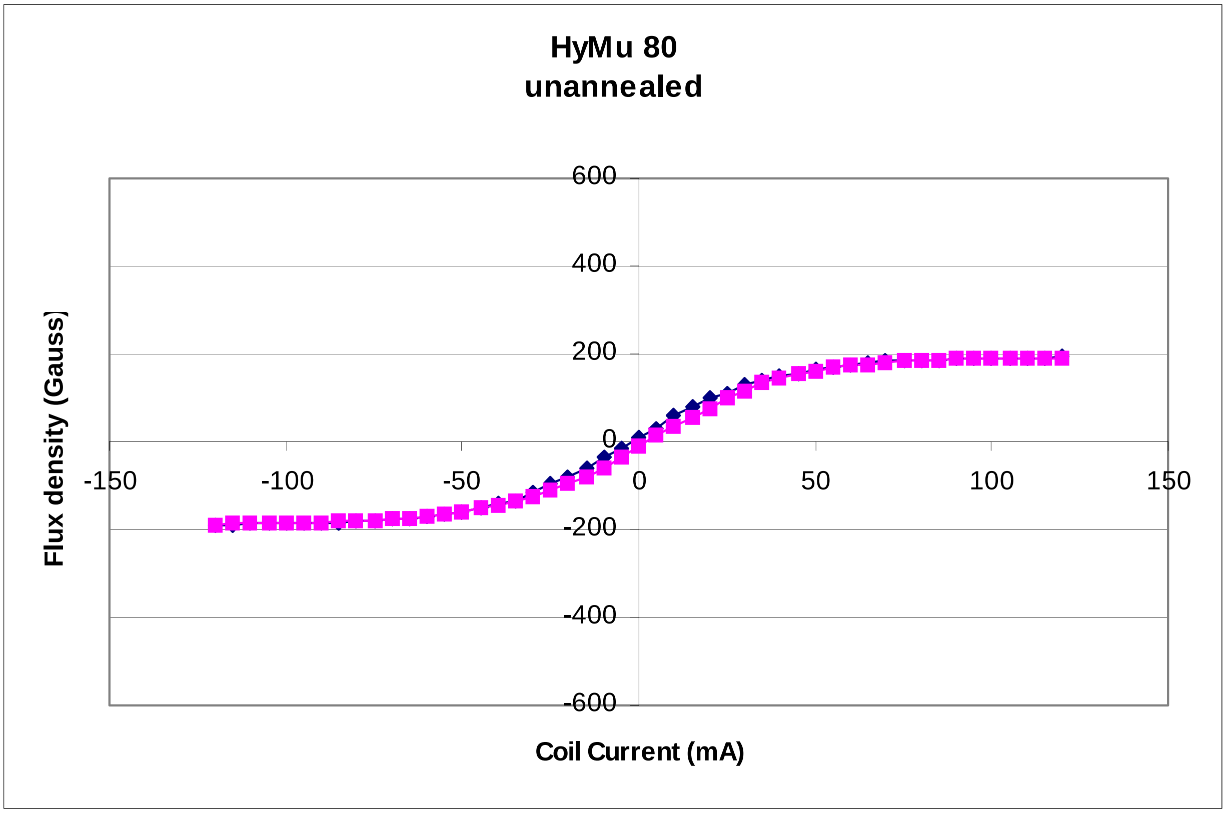

Figure 4

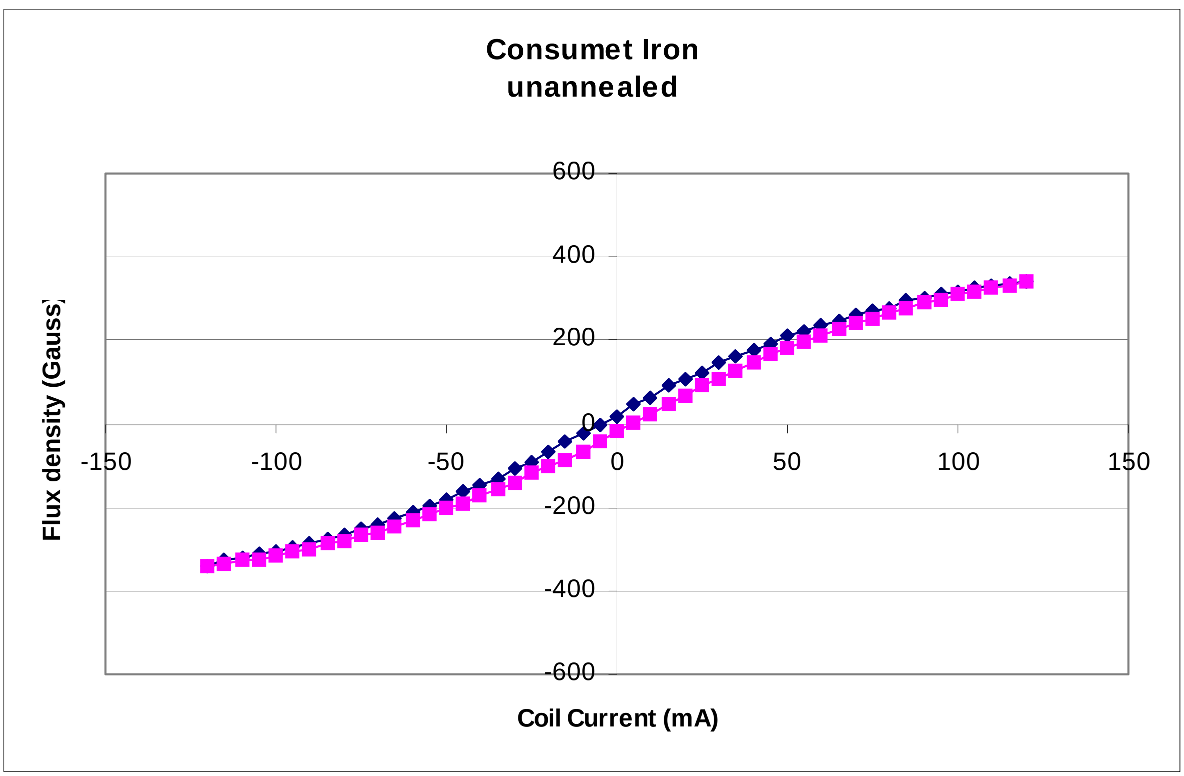

Figure 5

Annealing

Annealing of magnetic materials after machining is recommended. This was performed in a reducing atmosphere (dry Hydrogen) at 1500-1600 F (816-871 C), for 2-4 hours, then cooled at 180-400 F (82-204 C) per hour (recommended values for Hiperco 50A) [4]. Figures 6-9 show the measured flux density for the four materials after annealing, which should be compared to Figures 2-5, respectively. These figures clearly show that the saturation flux density increased for Hiperco 50A and Consumet, and the remenance was reduced slightly in all cases. In the case of Consumet iron which was not saturated before annealing, it is clearly saturated after annealing. In the case of HyMu 80, saturation occurs at a much lower coil current, and for Magnet iron the slope is reduced slightly.

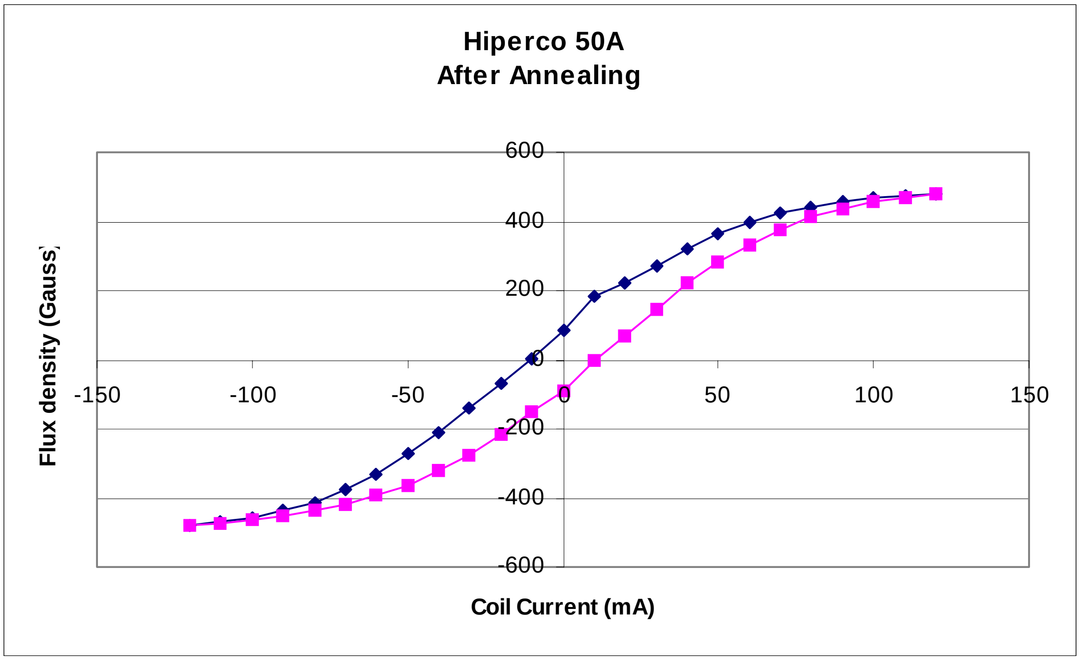

Figure 6

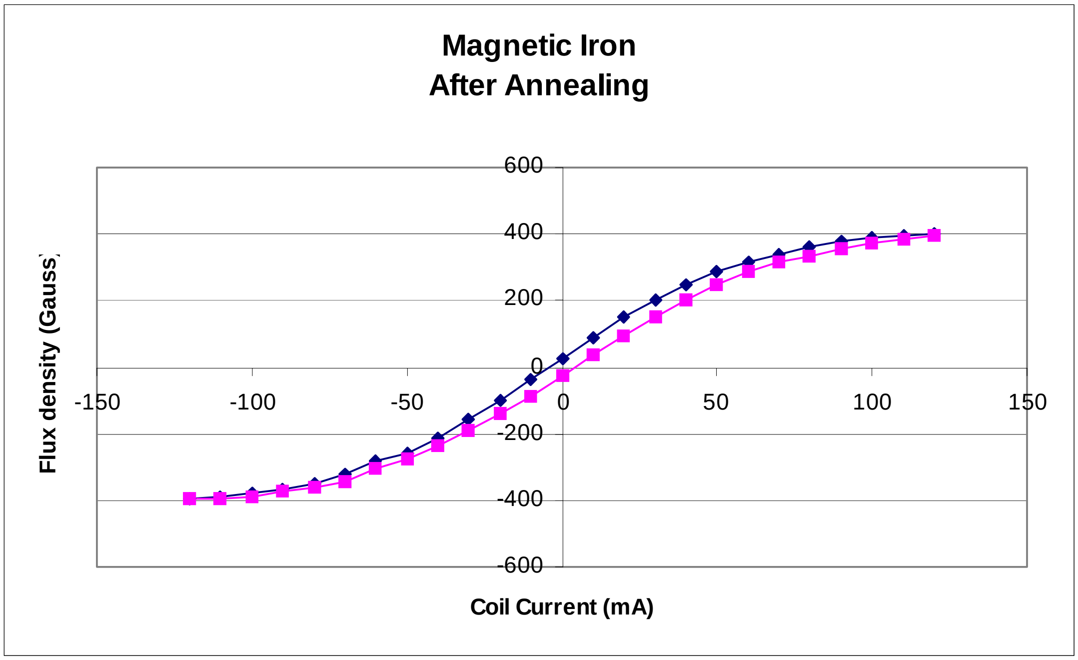

Figure 7

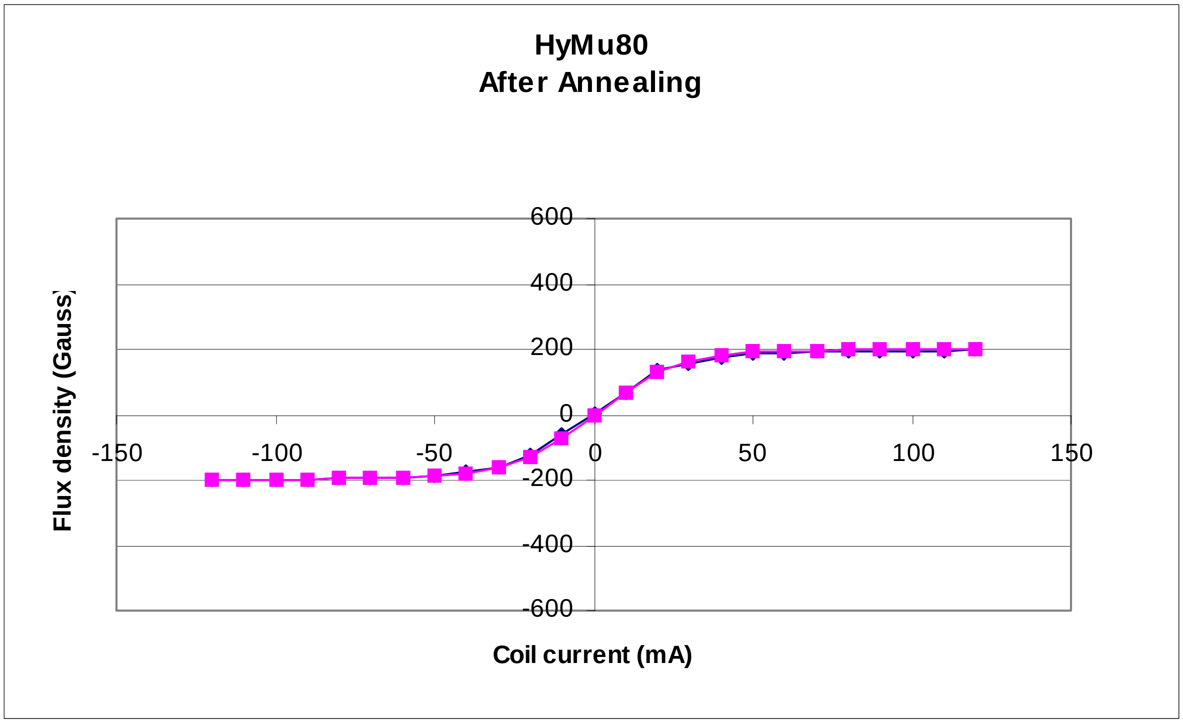

Figure 8

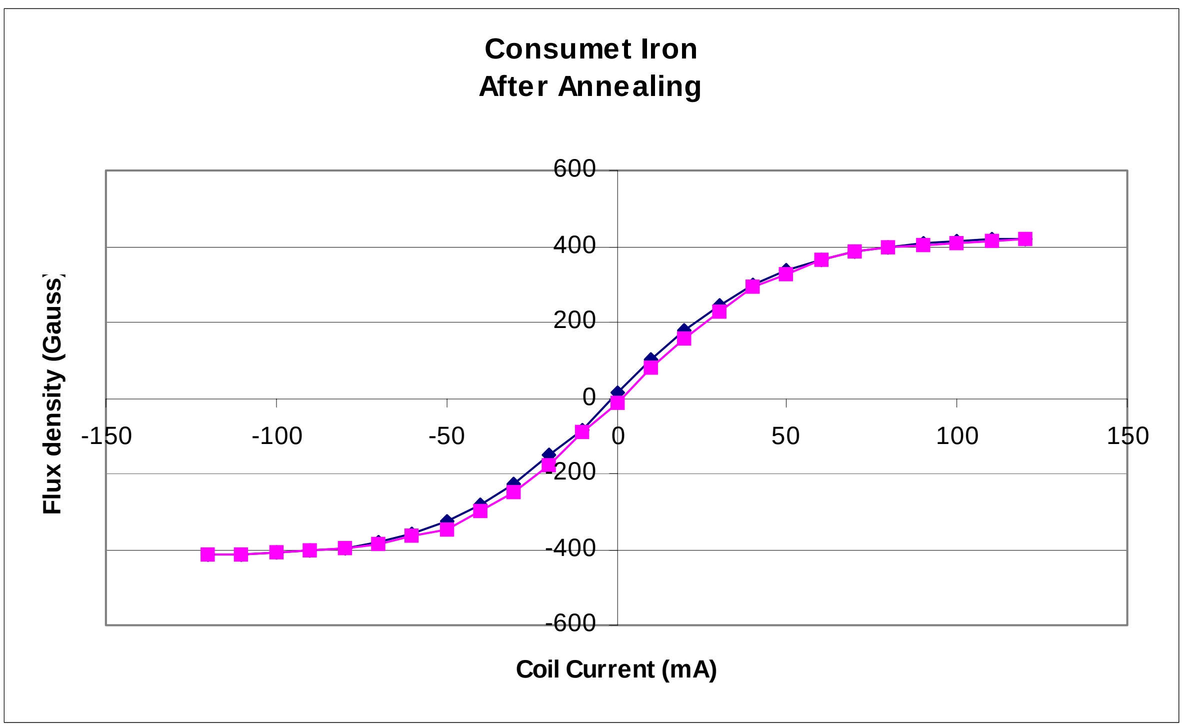

Figure 9

Corrosion

One concern with all these materials is their long-term corrosion behavior. To overcome this, the Consumet and magnetic iron samples were plated with 200 micro-inches (5.1 microns) of gold over 50 micro-inches (1.3 microns) of copper. There was no change in the behavior of the Consumet iron, but the magnetic iron appeared to saturate 10mA earlier. The reason for this is unknown. No change was observed when the gold and copper were removed between the contact points of the various sections of the magnetic circuit.

Cooling

The main selling point of Cryoperm 10 is that it has the same properties at 4 K as Mu metal at 300 K, even though Ackermann *et al.* [3] show no significant changes for iron and Hiperco 50 A on cooling. (HyMu 80 does change its maximum DC permeability and coercive force dramatically, but not its magnetic saturation.)

Conclusions

Four magnetic materials have been tested and ordinary magnetic iron has the best performance at room temperature, un-annealed. Consumet was the best when annealed, (if large remenance-hysteresis can be accepted, then Hiperco 50A can be used). It is therefore recommended that unannealed magnetic iron be used in the future. For comparison, Figure 10 shows one-half of the hysteresis curve for the four materials (all un-annealed) on the same plot, clearly showing the advantage of magnetic iron. Figure 11 shows the comparison for the annealed materials.
The relative maximum flux densities of the annealed materials are consistent with their relative Bstat values given in Table 1. For highest flux density for lowest drive current, annealed Consumet should be used.

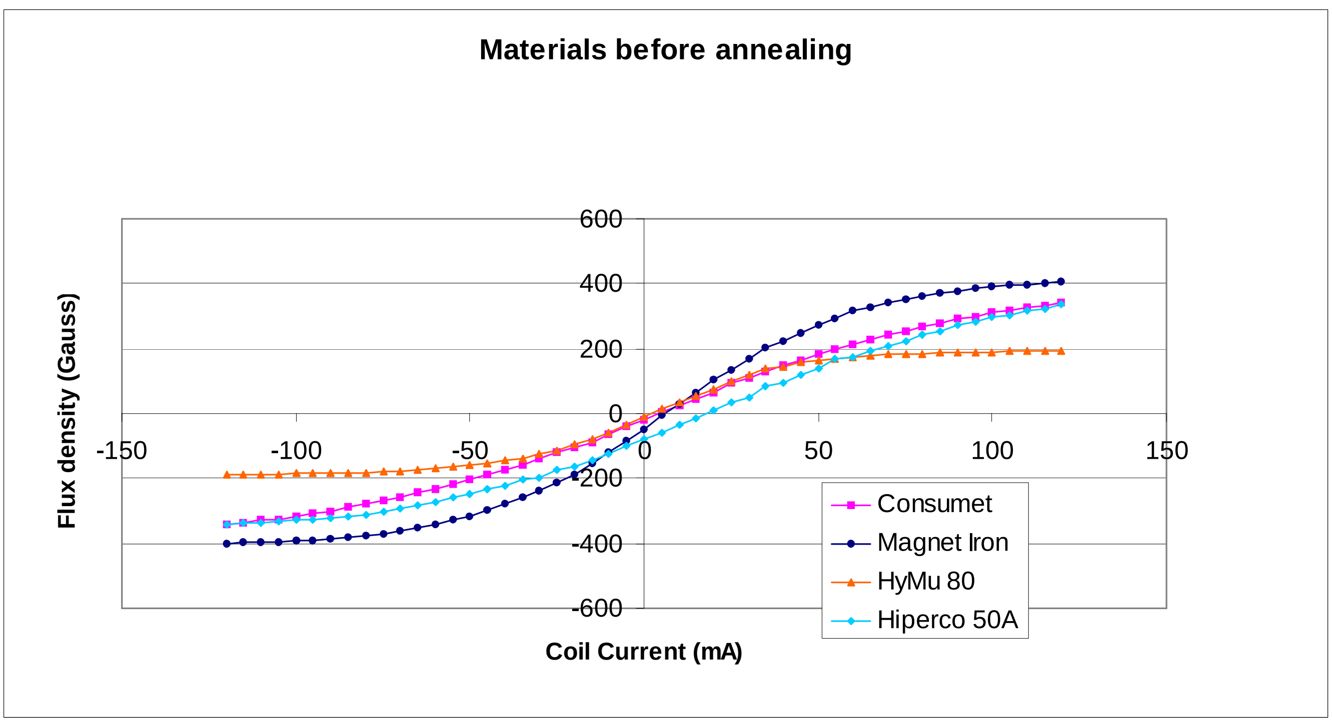

Figure 10

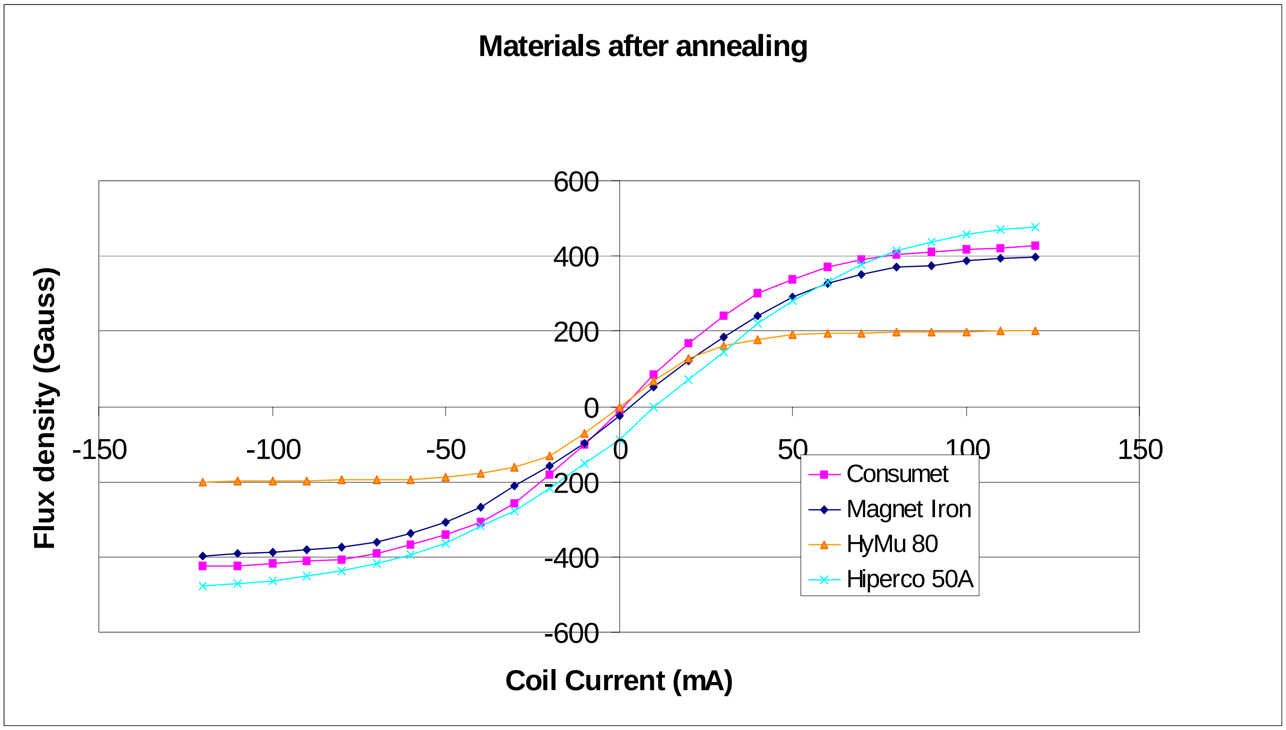

Figure 11

Acknowledgments

We wish to thank S. Claude (IRAM), R. Hesper/A. Baryshev (SRON), and C. Papa (CfA-Harvard) for information on the materials used at their institutes.

References

[1] G. A. Ediss, "Calculations of Magnetic Circuits for SIS Mixers," NRAO Electronics Division Technical Note 190, January 23, 2002. Available online at http://www.gb.nrao.edu/sshears/public_html/edtn/edtn190.pdf

[2] Scientific Alloys, Inc., Westerly, RI 02891 (401-596-4947).

[3] F. W. Ackermann, W. A. Klawitter and J. J. Drautman, "Magnetic Properties of Commercial Soft Magnetic Alloys at Cryogenic Temperatures," *Advances in Cryogenic Engineering*, Ed. K. D. Timmerhaus, vol. 16 (1971), pp. 46-50.

[4] Owego Heat Treat, Inc., 1646 Marshland Rd., Apalachin, NY 13732 (607-687-2091).